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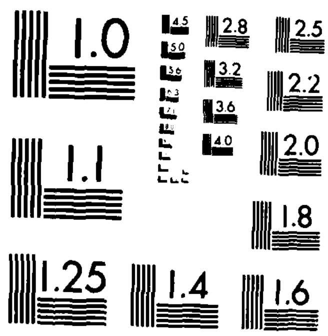

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Report No. CG-D-8-85

SWATHGEN COMPUTER-AIDED DESIGN SYSTEM USER'S MANUAL

FEBRUARY 1985

FINAL REPORT

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16. Abstract

SWATHGEN IS AN INTERACTIVE COMPUTER-AIDED DESIGN PROGRAM FOR SWATH SHIPS, WRITTEN IN FORTRAN 77 ON A VAX 11/780. IT USES TEMPLATE GRAPHICS SOFTWARE FOR PLOTTING. THIS PROGRAM PRODUCES FAIRED HULL FORMS, INCLUDING FAIRING OF THE STRUT-LOWER HULL INTERSECTION. SWATHGEN INTERFACES WITH A RESISTANCE CALCULATION PROGRAM, REPOW, AND A WAVE RESISTANCE OPTIMIZATION PROGRAM, OPTVOL, WHICH CONTOURS THE LOWER HULL TO MINIMIZE WAVE RESISTANCE. SWATHGEN PRODUCES A COMPLETE MATHEMATICAL DESCRIPTION OF THE HULL SURFACE GEOMETRY USING PARAMETRIC CUBIC SPLINES. THIS DESCRIPTION IS USED TO PRODUCE PLOTS (STATIONS, WATERLINES AND 3-D VIEWS), TO CALCULATE HYDROSTATIC PROPERTIES AND TO GENERATE A SOURCE PANEL DISTRIBUTION FOR WAVE RESISTANCE CALCULATIONS.

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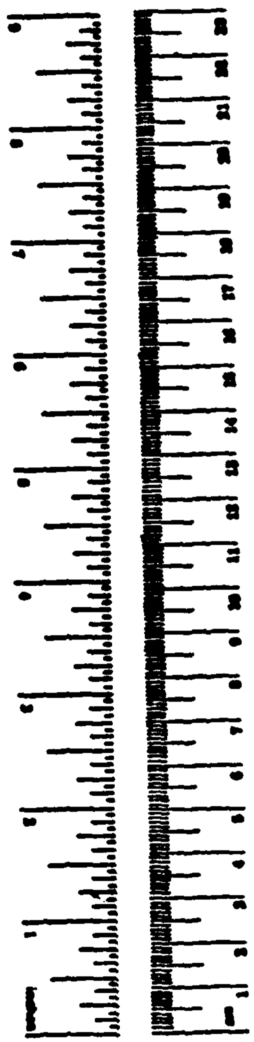
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

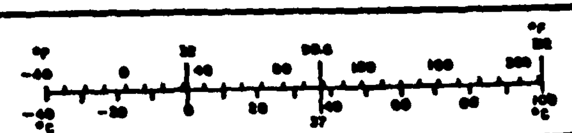


TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

1.0 INTRODUCTION

SWATHGEN is an interactive computer-aided design program for SWATH ships, written in ANS1 standard FORTRAN (FORTRAN-77). It uses TEMPLATE graphics software for plotting. This program produces faired hull forms, an example of which is shown in Figure 1-1. SWATHGEN interfaces with a resistance calculation program, REPOW, and a wave resistance optimization program, OPTVOL, which contours the lower hulls to minimize wave resistance. SWATHGEN produces a complete mathematical description of the hull surface geometry using parametric cubic splines. This description is used to produce plots (stations, waterlines and 3-D views) to calculate hydrostatic properties and to generate a source panel distribution for wave resistance calculations.

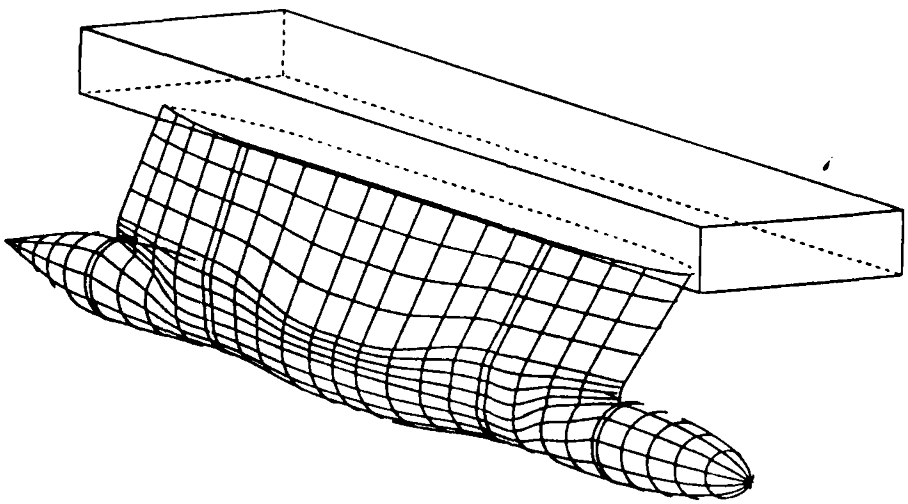


Figure 1-1. Example SWATH Hull.

Figure 1-2 shows a flowchart of the major components of SWATHGEN and Figures 1-3 and 1-4 show flowcharts of all the subroutines in REPOW and OPTVOL, respectively.

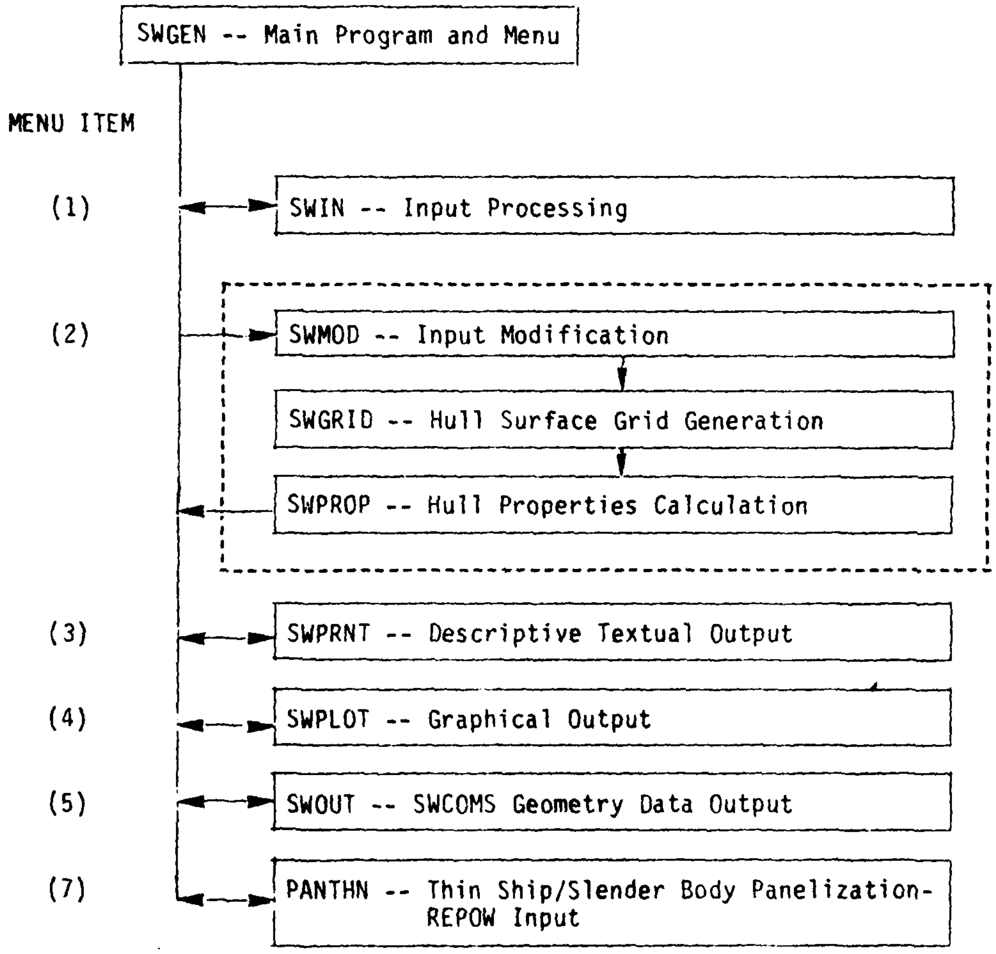


Figure 1-2. SWATHGEN Computer-Aided Design System

REPOW

Menu Item

- 1 INPT -- Read in source panel data
  - PANCHK -- Calculate source distribution properties
    - MATRX -- Find source panel transformation matrix
- 2 PANPLT -- Plot 3-D view of source panels
- 3 OPTSPC -- Find free surface spectrum for strut for OPVTOL input
  - WSPEC -- Find free surface spectrum
    - COEF -- find wavenumbers and initialize spectrum calculation
    - LINE -- find the contribution of a source line
    - PANEL -- find the contribution of a source panel
      - MATRX
  - OUTPT -- Write the spectrum to a data file
- 4 RESIN -- Calculate resistance versus speed
  - WSPEC
    - COEF
    - LINE
    - PANEL
      - MATRX
  - RES -- Find all resistance components
- 5 RESPLT -- Plot resistance versus speed
  - TEMPLATE Graphics subroutines
- 6 RESOUT -- Output resistance data

Figure 1-3. REPOW Flow Diagram

OPTVOL -- Determines a hull form of low wave resistance for a SWATH

- INPT -- Reads in geometry and free surface spectral data for the SWATH strut
- MINMIZ -- Sets a system of linear equations whose solution is the optimized source distribution representing the SWATH lower hull
- SAXB -- Solves a system of linear equations
  - RLUD -- Matrix decomposition
  - RFBS -- Forward/backward substitution
- DIAMIR -- Finds the lower hull radius distribution represented by the source distribution
- RERITE -- Creates an input data file for SWATHGEN representing the new lower hull

Figure 1-4. OPTVOL Flow Diagram

To describe the SWATH ship, the user inputs a description for each of three components: the upper hull or "box", the strut and the lower hull and their relative positions and orientations. The box is modelled as a simple rectangular prism. The strut cross-sections have an elliptical nose, parallel midsection and a parabolic tail. The strut leading and trailing edges may be inclined, its midship section may taper, and it can be oriented arbitrarily in space. The lower hull is described by elliptical or circular cross-sections distributed along a centerline.

The program then constructs a fairing surface between the lower hull and the strut, controlled by a small set of parameters input by the user (No fairing is done between the box and strut.) The fairing surfaces are constructed using circular arc segments and straight lines. The complete description of the hull form (the starboard side only -- port/starboard symmetry is assumed) is saved and the user may evaluate it using the output facilities of SWATHGEN. Modifications to any of the inputs can be made interactively at any time.

SWATHGEN, REPOW and OPTVOL are all highly interactive programs. To allow the most flexible use of the many capabilities of SWATHGEN and REPOW, these codes are largely menu-driven -- the user is provided with numbered lists of program functions to choose from. This gives direct control of program flow to the user. Since OPTVOL performs a single function, it does not make use of menus. It is, however, interactive in that all of the required input is explicitly requested by the program.

The main menu for SWATHGEN is shown in Figure 1-5. The remainder of this manual describes each of the subroutines accessed by this menu and the functions of REPOW and OPTVOL.

```
*************
SWATHGEN MENU
*************
    1) SWIN (,SWMOD,SWGRID,SWPROP) - generate hull form
    2) SWMOD,SWGRID,SWPROP - modify hull form
    3) SWPRNT - descriptive printout
    4) SWPLOT - plots
    5) SWOUT - create SWCOMS output or DUPLICATE INPUT data files
    6) NAME OR RENAME HULL
    7) PANTHN - panelization for REPOW/OPTVOL input
 ENTER YOUR CHOICE 1-6, 'O' TO STOP
```

Figure 1-5. SWATHGEN Main Menu.

The remainder of the manual describes the usage of SWATHGEN and details the executions of each of the subroutines shown in Figures 1-2, 1-3 and 1-4. Sample runs are given in Appendix C.

ACKNOWLEDGMENT

The development of the SWATH computer-aided design programs and the technology they are based on has been a cooperative effort supported jointly by the United States Coast Guard, the Office of Naval Research, and Naval Sea Systems Command. The programs have been installed on a VAX 11/780 at NAVSEA and is available to the U.S. Coast Guard and Navy design community.

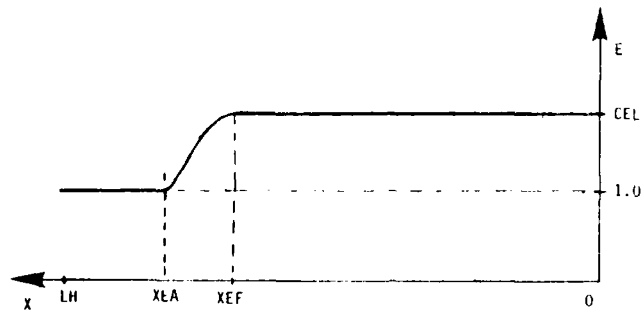


Figure 2-11. Elliptical Ratio Distribution

3) Positioning and Orienting the Lower Hull

The orientation of the lower hull is set by the nose-up and toe-out angles, indicating rotation in the Y-Z and X-Y planes respectively, and shown below in the positive sense, Figure 2-12

The position of the lower hull in the strut coordinate system is specified by the position of the nose of the lower hull or by the position of its midship section. The latter may be used to more easily align the strut and lower hull. As shown below, the user enters three values to specify the position - XN, YN, ZN for the nose position, or XN, D, H for the midship position. The program distinguishes the two methods by the sign of the third value, ZN is always negative, while H is always positive.

```
 ENTER NOSE-UP AND TOE-OUT ANGLES (DEG).
0 0

 LOCATE HULL RELATIVE TO STRUT LE (STRUT COORDS: X +AFT, Y +STBD, Z +UP

 ENTER : (XN,D,H)    TO SET POSITION AT MIDSHIP (H POSITIVE)
      OR (XN,YN,ZN)   TO SET NOSE POSITION

    WHERE: (XN,YN,ZN) = THE COORDINATES OF THE LOWER HULL NOSE
                    H = THE LOWER HULL CENTERLINE DEPTH AT MIDSHIP
                        TO THE STRUT CENTERPLANE
                    D = THE DISTANCE AT MIDSHIP FROM THE LOWER HULL
                        CENTERLINE
```

2) Lower Hull Ellipticity

The elliptic ratio, E, is defined as the ratio of the horizontal axis length to the vertical axis length for each section of the lower hull, as shown below

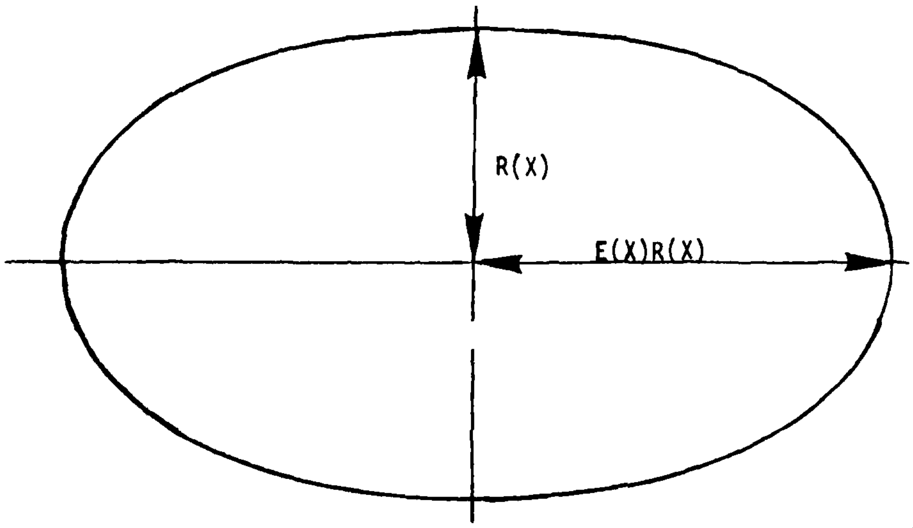


Figure 2-10. Elliptic Ratio Definition
(This shows E=1.79)

To define its longitudinal distribution, the user inputs the boundaries of a transition region in which the cross-sections start with the input elliptic ration of CEL and moving aft change to a value of 1.0, as shown below, Figure 2-11

```
ENTER  CEL,XEF,XEA  WHERE:

       CEL = RATIO OF HORIZONTAL AXIS LENGTH TO VERTICAL AXIS LENGTH
       XEF = DISTANCE FROM NOSE ALONG HULL CENTERLINE
             TO BEGIN BLENDING TO CIRCULAR SECTION BEGINS
       XEA = DISTANCE FROM NOSE ALONG HULL CENTERLINE
             WHERE SECIONS BECOME CIRCULAR
             NOTE: MUST HAVE XEA>XEF
                   SET CEL=1. FOR ALL CIRCULAR SECTIONS
                   SET XEF>HULL LENGTH FOR ALL ELLIPTIC SECTIONS
                   HULL LENGTH =        0.000000
```

METHOD 4

In the parametric lower hull definition, the vertical radius is elliptical in the nose section, constant in the midsection, and parabolic in the tail section. These parameters are input as shown below.

```
PARAMETRIC LOWER HULL DESCRIPTION
------------------------------
        HL1 = ELLIPTIC FOREBODY LENGTH
        HL2 = PARALLEL MID-BODY LENGTH
        HL3 - PARABOLIC TAIL SECTION LENGTH
        RMAX = MID-BODY RADIUS
 ENTER HL1,HL2,HL3,RMAX
```

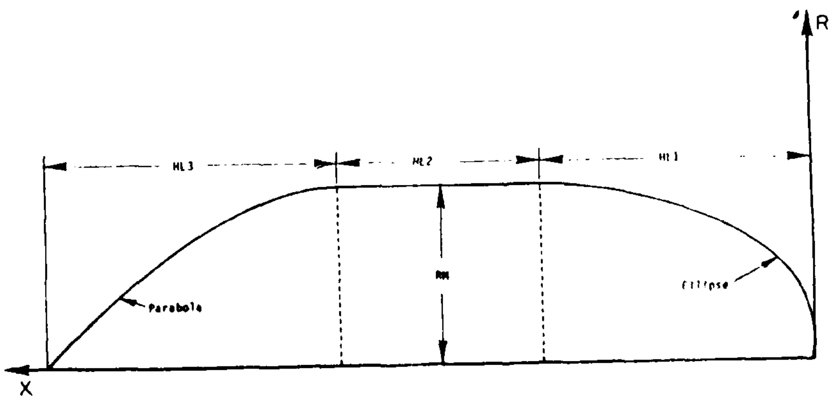


Figure 2-9. Parametric Lower Hull Description.

METHOD 3

A set of X,R, input points is called for, as shown below. Then the user must enter the first and last points which will be filleted. Forward of this first point and aft of the last, the midpoint spline is used. In between the points are connected with straight lines and the sharp corners are rounded with the specified fillet radius.

```
 ENTER X,R PAIRS.  STARTING  WITH THE NOSE (Xn,0) AND ENDING
 WITH THE TAIL (Xt,0)
POINT  1:
       .
       .
       .

 ENTER NUMBERS OF THE FIRST AND LAST POINTS FOR FILLETING
 OR ENTER (0,0) FOR DEFAULTS
2 5
 ENTER RADIUS OF FILLETS BETWEEN SEGMENTS
3
```

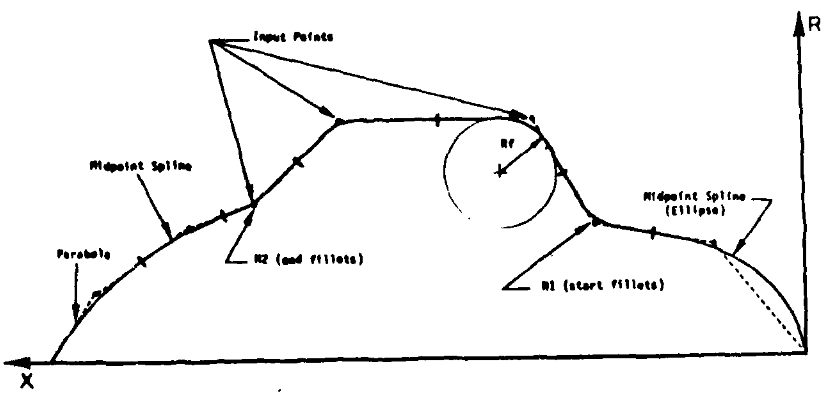


Figure 2-8. Method 3 - Filleted Cones and Cylinders

```
ENTER X,R PAIRS.  STARTING  WITH THE NOSE (Xn,0) AND ENDING
WITH THE TAIL (Xt,0)
POINT  1:
```

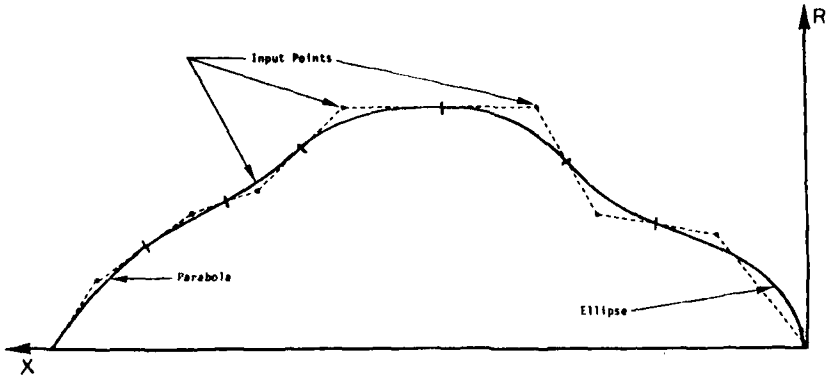


Figure 2-6. Method 1 - Midpoint Spline

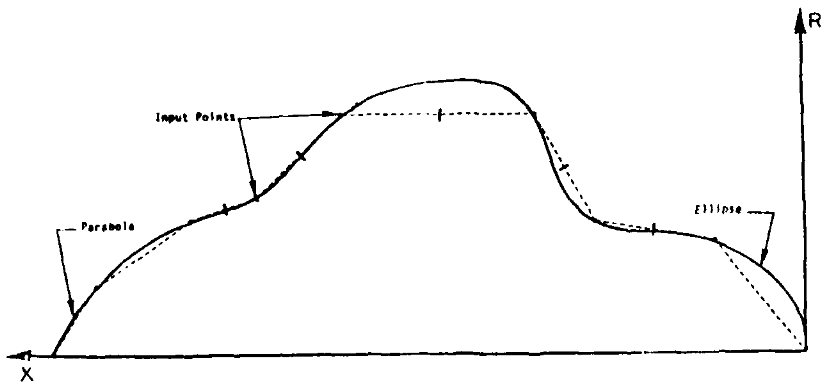


Figure 2-7. Method 2 - Curve Fit Through Points

1) Vertical Axis Radius Distribution

The profile of the lower hull is defined in its local coordinate system - the x-axis is the hull centerline, positive aft. (The horizontal radius is defined later by the elliptic ratio.) Four methods are available for specifying this distribution;

```
CHOOSE A METHOD FOR DEFINING THE LOWER HULL:

              CURVE FIT TO (X,R) OFFSETS
 1)  CURVE TANGENT TO MIDPOINTS OF CONNECTING SEGMENTS
 2)  CURVE FIT THROUGH POINTS
 3)  FILLETTED CONES AND CYLINDERS WITH SMOOTHED NOSE AND TAIL

              PARAMETRIC DESCRIPTION
 4)  ELLIPTIC-PARALLEL-PARABOLIC HULL

ENTER 1,2,3, OR 4
```

METHOD 1

A set of X,R input points if called for as shown below and a cubic spline is fitted tangent to the midpoints of the segments connecting the points. An ellipse is fitted between the nose and the second midpoint and a parabola between the tail and the second-to-last midpoint, as shown in Figure 2-6.

```
 ENTER X,R PAIRS.  STARTING  WITH THE NOSE (Xo,0) AND ENDING
 WITH THE TAIL (Xt,0)
POINT  1:
```

METHOD 2

A set of X,R input points is called for, as shown below, and a cubic spline is fit through these points. At the nose the curve is required to be blunt and approximates an ellipse. The last section is parabolic.

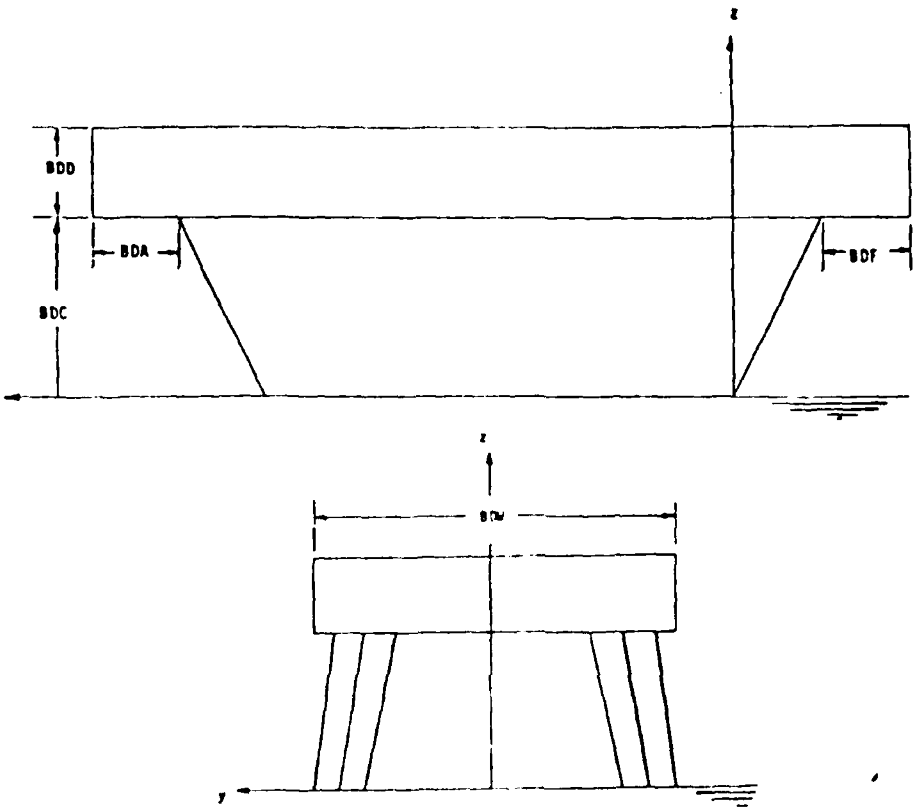


Figure 2-5. Box Dimensions

2.3 Lower Hull Input

The lower hulls are defined by a distribution of elliptical cross-sections along a centerline. The user specifies the distribution of the radius of the vertical axis of the elliptical sections, the ellipticity of the sections, and the position and orientation of the lower hull.

The strut cant angle represents rotation about the strut's original x-axis, positive as shown in Figure 2-4. The toe-out angle indicates rotation about the z-axis of the strut coordinate system, shown in its positive sense in Figure 2-3. Note that these two angles are independent.

The strut separation, SSS, is the distance between the port and starboard struts on the design waterline, at their leading edges. This dimension is shown in Figures 2-3 and 2-4.

2.2 Box Input

The upper hull is modelled as a simple rectangular prism to be denoted as the box. This object is not included in any calculations, but is simply a visual aid, to make the plots somewhat more coherent. To specify the dimensions and location of the box, the user must input five parameters:

```
... BOX DESCRIPTION...

ENTER BDD,BDC,BDF,BDA,BDW WHERE:
  BDD = BOX DEPTH
  BDC = CLEARANCE ABOVE WATERLINE
  BDF = FORWARD OVERHANG(FAST STRUT)
  BDA= AFT OVERHANG(FAST STRUT)
  BDW = BOX WIDTH
```

As shown in Figure 2-5, BDC gives the clearance of the box above the waterline and so defines the top of the strut as well.

The two overhangs, shown positive in Figure 2-5, define both the length and fore and aft position of the box. The box width is the total for port and starboard.

```
-STRUT ORIENTATION-
ENTER SAC,STO,SSS WHERE:
  SAC = STRUT CANT ANGLE (DEG)
  STO = STRUT TOE OUT ANGLE (DEG)
  SSS = STRUT SEPARATION AT LEADING EDGE ON WATERLINE
```

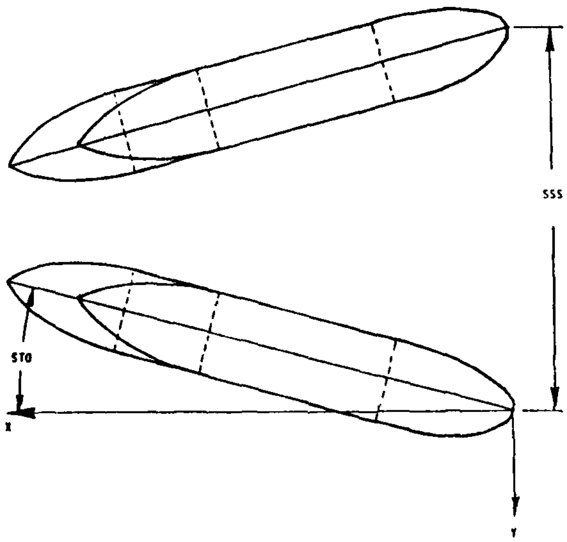


Figure 2-3. Strut Position and Orientation (Global Coordinate System)

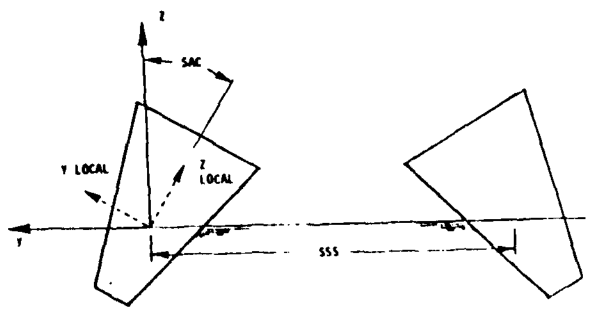


Figure 2-4. Cant Angle and Strut Separation (Looking Aft)

Then only two more parameters define the fairing strut -- the distance which the overhang strut overhangs it and the length of its parabolic tail:

```
 - STRUT OVERHANG PARAMETERS-
 ENTER SOV,SF3 WHERE:
   SOV = STRUT OVERHANG PAST THE FAIRING TRAILING EDGE
   SF3 = LENGTH OF STRUT PARABOLIC TRAILING SECTION FOR FAIRING
         SET SOV=0 FOR NO OVERHANG
```

As noted, if SOV is set SOV=0, then there is no overhang and the value of SF3 is ignored.

Now the vertical variation of the strut waterplanes is defined. These parameters are the same for both the fairing and overhang struts.

```
-STRUT VERTICAL PARAMETERS BEFORE CANTING-
ENTER SAT,SAF,SAA WHERE:
  SAT = TRANSVERSE TAPER HALF ANGLE (DEG) OF FLAT SIDES
  SAF = INCLINATION ANGLE (DEG) OF LEADING EDGE (+ AFT, 0.0 FOR VERTIC
  SAA = INCLINATION ANGLE (DEG) OF TRAILING EDGE (+ AFT, 0.0 FOR VERTIC
```

The fore and aft inclinations of the leading and trailing edges of the struts are specified: SAA and SAF. The leading edge angle is repeated in the inclination of the forward edge of the parallel section and the trailing edge angle in its aft end. The taper of the strut thickness is specified as SAT. These three angles are input in degrees and are shown in the positive sense in Figure 2-2. The section showing SAT is a cut through the parallel section of the struts, perpendicular to the plane of symmetry and the waterplane.

Finally the strut must be oriented in space, in the strut coordinate system (see Appendix A).

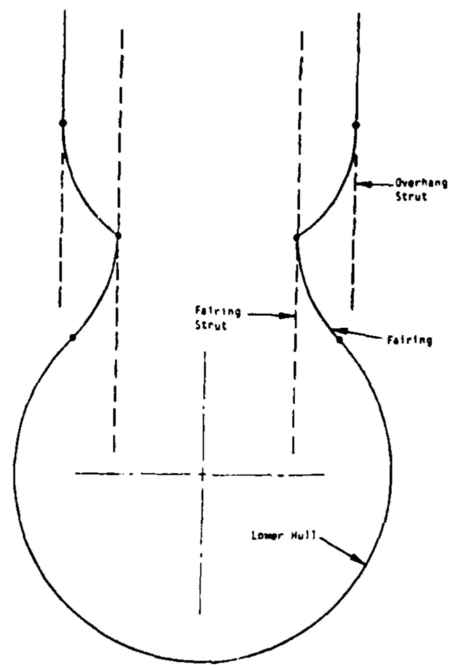


Figure 2-1. Overhang Construction

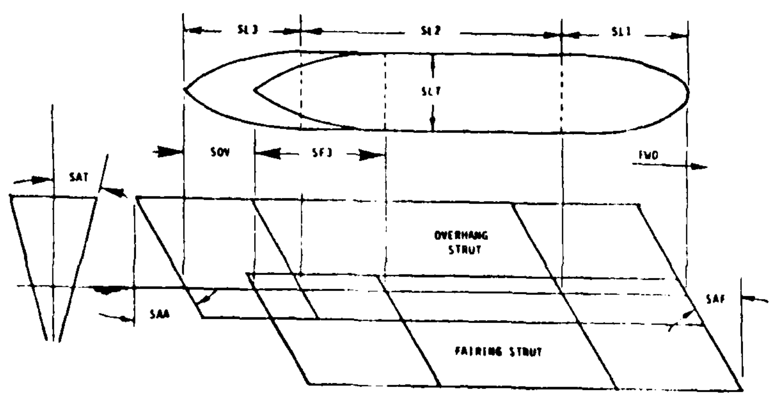


Figure 2-2. Strut Definition

2) The variation of this waterplane in the original vertical direction is specified, to define a solid body, with its top and bottom undefined.

3) This solid body is placed in space and given an arbitrary orientation.

In order to include an overhang at the aft end of the strut, two struts are defined. The upper strut is called the "overhang" strut and extends from the bottom of the box downward. The lower strut is called the "fairing" strut and extends upwards from the intersection with the lower hull. The fairing strut is used to construct a hull with no overhang, using the grid generation/fairing methods described in Chapter 4. The overhang strut is then superimposed on this hull. A section through a typical overhang is shown in Figure 2-1, with the original fairing and overhang struts shown as dotted lines.

In step 1, the waterplanes of the two struts are defined. Figure 2-2 shows the waterplanes and an elevation. Each has a nose section which is half of an ellipse, a rectangular midsection, and a tail composed of two parabolas, forming a sharp trailing edge. The overhang strut and fairing strut have the same nose section and thickness. First the overhang strut waterplane is defined -- all the parameters are shown in Figure 2-2 (the prompts given by SWATHGEN are shown throughout this chapter):

```
-STRUT WATERPLANE PARAMETERS BEFORE CONTING-
ENTER SL1,SL2,SL3,SLT WHERE:
  SL1 = ELLIPTIC FOREBODY LENGTH
  SL2 = PARALLEL MIDBODY LENGTH
  SL3 = PARABOLIC TAIL LENGTH
  SLT = MIDBODY WIDTH
```

The third source of geometry input is the "SWCOMS" file, which contains the input geometry, the final faired hull geometry and all of the calculated hull form properties. The SWCOMS file creation is discussed in detail in Chapter 7 and Appendix B. Using SWIN options 6, 7 and 8 the user can extract the strut, box or lower hull data from an SWCOMS file. With any of these three options, the same data read in options 1, 2 and 3 is read from the SWCOMS file.

If option 5 is chosen, all of the input data is read from the SWCOMS file, including the complete surface definition. This data also includes all of the inputs required to guide the fairing between the strut and lower hull -- the fairing parameters, which would otherwise be requested of the user later on, in the subroutine SWMOD.

With these 5 input options, the user may freely mix the inputs from several sources, then supersede them with new inputs. In any case, the program keeps track of what has been input and will inform the user if insufficient data is available. Similarly, it will not perform unnecessary calculations. Therefore, if the user reads in an SWCOMS file with input option 5, he may proceed directly to output operations from the main menu.

The rest of this chapter details the input which defines the three components of the hull. The definitions of the input are given in the order in which the program calls for them when taking terminal input. The fairing parameters, when input at the terminal, are given in the routine SWMOD and are covered in Chapter 3.

2.1 Strut Input

The strut is defined in three steps;

1) The original strut design waterline is defined.

2.0 SWIN-SWATH CONFIGURATION INPUT ROUTINE

To define the SWATH geometry, SWATHGEN takes simple geometry for three components -- strut, box and lower hull -- and a set of parameters guiding the strut-to-lower hull fairing, and fairs them together to create a single continuous surface representing the starboard hull. Before performing any operations with SWATHGEN, the user must provide the program with data for the three components or the data for the final surface representation. The input routine allows several methods and sources for these inputs and the user has another menu, shown below, to control the input.

```
=========
SWIN MENU
=========
  1) ENTER STRUT DATA
  2) ENTER BOX DATA
  3) ENTER LOWER HULL DATA
  4) 1,2,AND 3 IN SEQUENCE
  5) READ IN SWCOMS FILE FOR EXISTING HULL
  6) READ ONLY STRUT DATA FROM AN SWCOMS FILE,
  7) READ ONLY BOX DATA FROM AN SWCOMS FILE
  8) READ ONLY LOWER HULL DATA FROM AN SWCOMS FILE
ENTER CHOICE 1-8,  RETURN TO EXIT SWIN
```

If options 1, 2, 3 or 4 are chosen, the user can then choose to enter the required values at the terminal -- in which case all input is explicitly requested by the program or from a data file. In either case the data is read in the same format and in the same order. The format is FORTRAN "star" (*) format, which requires only that the values input be separated by a space, a comma, or a carriage return. Decimal points are not required when entering whole real numbers and the exponential form may be used.

After entering the data for any of the three components, the program creates a data file containing this data in the same order in which it was entered -- a "duplicate" file. This file may then be used later to repeat the inputs.

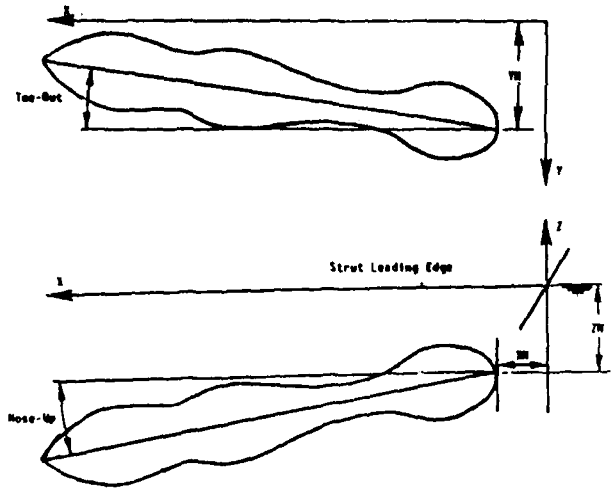


Figure 2-12. Lower Hull Position By Nose Coordinates

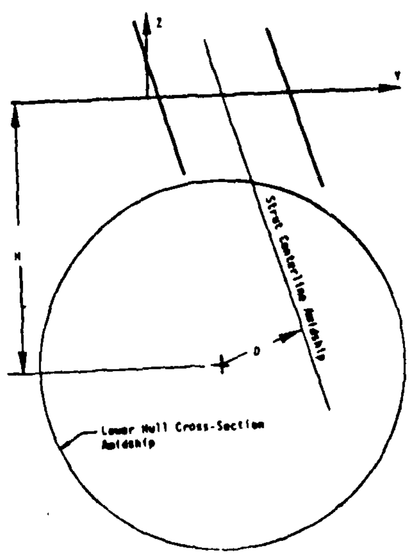


Figure 2-13. Lower Hull Position Amidship

3.0 SWMOD - GEOMETRY MODIFICATION

This routine allows the user to modify any or all of the inputs defining the hull geometry. It also allows the input of the fairing parameters, which guide the strut/hull connection. The user may make several other geometry modifications and also create a three-dimensional plot of the unfaired SWATH components.

SWMOD has its own control menu;

```
==========
SWMOD MENU
==========
    NOTE:  THE VALUE '0' WILL LEAVE ANY VALUE UNCHANGED IN THE ROUTINES
     BELOW OR INVOKE A DEFAULT VALUE IF THE VARIABLE HAS NOT BEEN PREVIOUSLY
       SET (ENTER 1.E-6 IF A ZERO VALUE IS REQUIRED.)

        1) MODIFY LOWER HULL ONLY
        2) MODIFY STRUT ONLY
        3) MODIFY BOX ONLY
        4) SET OR MODIFY FAIRING PARAMETERS
        5) CHANGE DESIGN WATERLINE
        6) RESCALE ENTIRE HULL CONFIGURATION
        7) PLOT UNFAIRED HULL CONFIGURATION
        8) RETURN TO SWATHGEN MENU

 ENTER SWMOD CHOICE 1-8, OR HIT RETURN TO RUN SWGRID
```

When modifications are complete, the user may return to the SWATHGEN menu, if desired, but only by entering a "RETURN" and running SWGRID can the changes be incorporated in the SWATHGEN surface definition. Note that entering the fairing parameters is an option, number 4. If the user attempts to continue and run SWGRID without having entered the fairing parameters in this way, or from an SWCOMS file in the input routine, the program will automatically ask for these parameters.

The rest of this chapter describes the SWMOD options.

3.1 Input Geometry Modification

If SWMOD option 1, 2 or 3 is chosen the user may change the parameters defining the lower hull, strut and box, respectively, exactly as they were defined in Chapter 2. As noted in the SWMOD menu, however, entering a value of 0 (zero) for any parameter maintains the original value.

3.2 Fairing Parameters

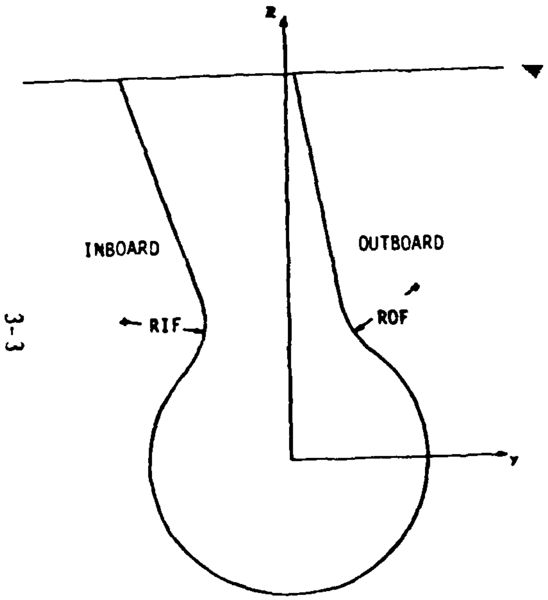
The smooth surface connecting the strut and the lower hull is constructed according to the parameters set in this option of SWMOD (see also Section 4). These parameters must be set before SWGRID is executed the first time through the design loop. During the first call to SWMOD, the user may elect to have the computer choose default values for some or all of the parameters by simply entering a "0" for a parameter value. The computer will choose a default value based on the strut-lower hull configuration. Once a parameter has been set, entering a zero value in subsequent calls to SWMOD will leave that parameter unchanged. If a value of zero is desired for a parameter, a small number, (1.E-6) should be entered.

a. IFTYP - Selects the outboard fairing method: 1, 2 or 3 (see Figure 3-1)

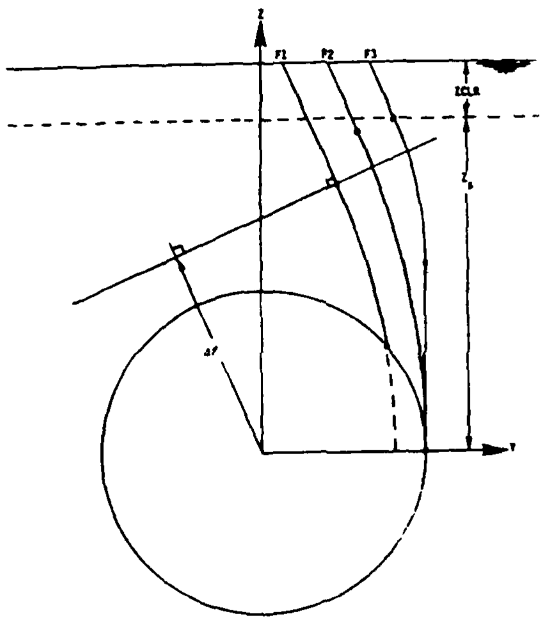
Method 1:
- Vertical or canted struts aligned with the lower hull

Method 2:
- Canted struts only
- Variable outer fairing radius

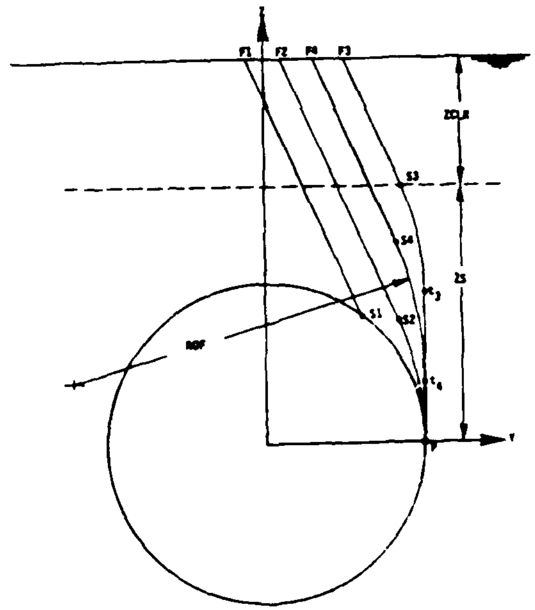
Method 3:
- Canted struts only
- Constant outer fairing radius
- Strut lines used as outboard mid-section fairing region boundaries must clear the lower hull surface



EXAMPLE FAIRING SECTION
FOR OUTBOARD FAIRING METHOD 1



EXAMPLES OF FAIRING CURVES
FOR OUTBOARD FAIRING METHOD 2



EXAMPLES OF FAIRING CURVES
FOR OUTBOARD FAIRING METHOD 3

b. ILETE - Selects the leading and trailing edge fairing method: (see Figure 3-2)

Method 1: Given radial distance DR from the lower hull, fair to lower hull normal

Method 2: Given DR, fair to lower hull at given y lower hull coordinate

Method 3: Given DR, fair to vertical at Z=0 (lower hull centerline)

c. DR(LE), DR(TE) - Radial distances from the lower hull surface at which to start fairing of leading and trailing edges

d. YLE, YTE - Y offsets from the lower hull centerline of the leading and trailing edge fairing-lower hull intersections (used only if ILETE = 2)

e. RIF - Inboard mid-section constant fairing radius

f. ROF - Outboard mid-section constant fairing radius (used only if IFTYP ≠ 2)

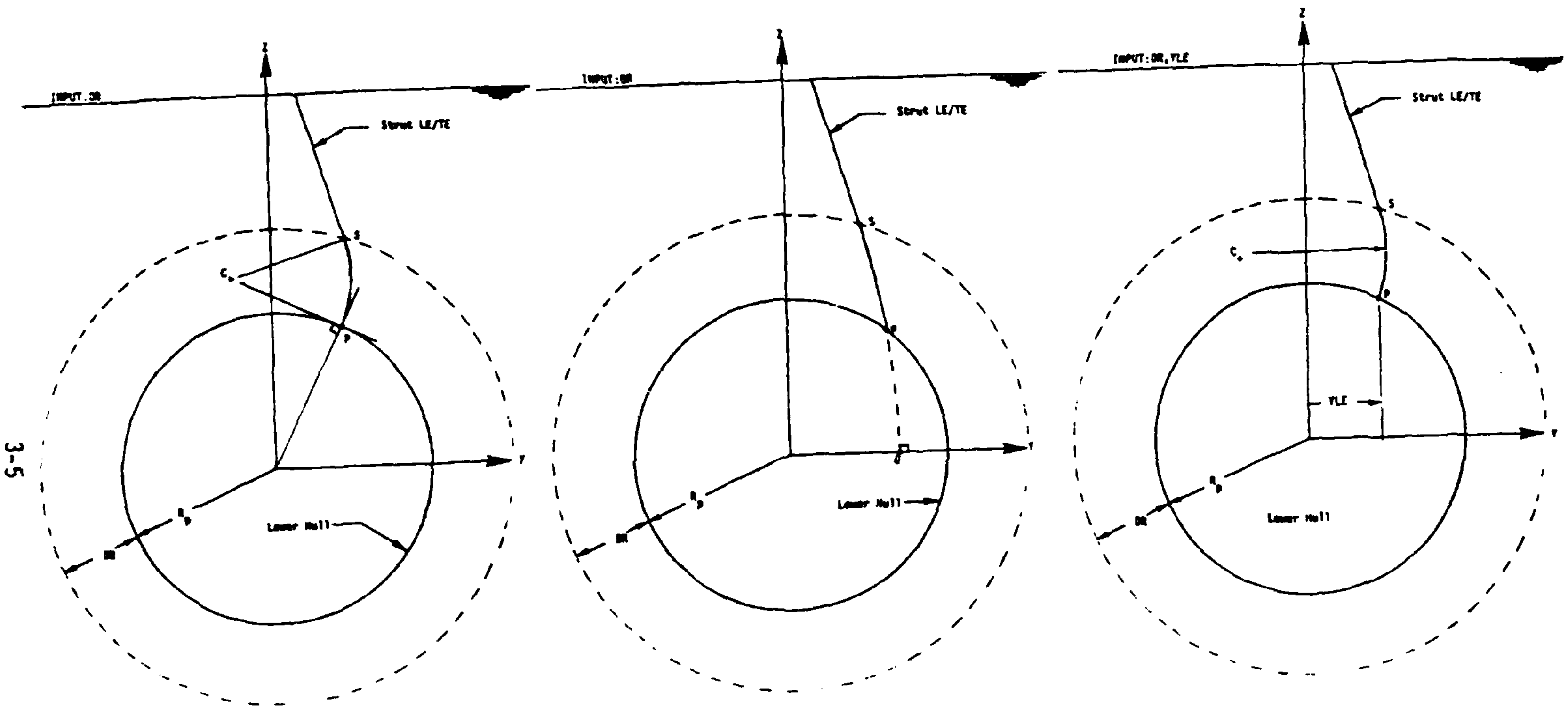
g. XOF, XOA, XIF, XIA

- These values set the outboard, fore and aft, and inboard, fore and aft, boundaries respectively for the mid-section fairing region of the hull in an approximate way

- Enter the values as fractions of the strut length from the leading edge to the forward boundaries and from the trailing edge to the aft boundaries

- Values must be fractions between 0. and 1. (see Figure 3-3)

h. ZCLR - Z coordinate of maximum fairing height (default: design waterline)



LE/TE FAIRING METHOD 1

LE/TE FAIRING METHOD 2

LE/TE FAIRING METHOD 3

Figure 3-2. Leading and Trailing Edge Fairing Methods

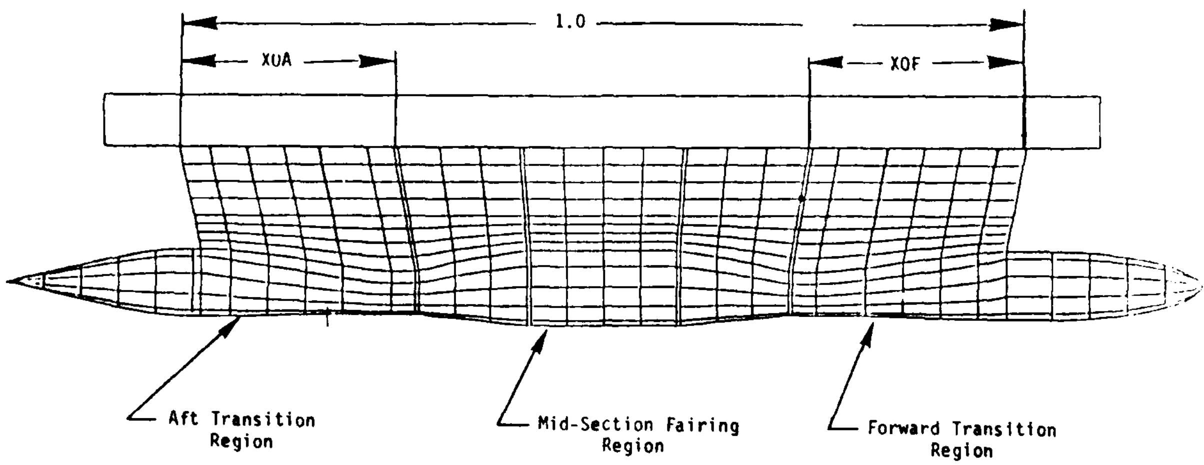


Figure 3-3. Fairing Region Boundaries

3.4.1 Fairing Suggestions

- Use the default function to set the fairing parameters the first time through the design loop and adjust the values on subsequent runs to achieve a nicely faired hull.

- Since the default values chosen by the computer depend on the initial strut-lower hull configuration, any major modifications to the strut or lower hull geometry should be made prior to setting the default fairing parameters.

3.3 Waterline Modification

The user may enter a sinkage value to raise or lower the waterline. The parameter ZCLR will also be adjusted by an identical amount so that the same fairing will be employed by SWGRID.

3.4 Rescale Entire Below Waterline Hull

This option rescales the lower hull, strut and box dimensions by the factor entered by the user. Note: Fairing parameters ROF, RIF, DR(LE), DR(TE), YLE and YTE will be scaled by the same factor.

3.5 Plot the Unfaired Hull

This option allows the user to view the unfaired hull configuration before constructing the fairing surface. The routine plots the strut leading and trailing edges and the strut parallel mid-section borders. Strut z cross-sections are shown at the waterplane, the box intersection and at some z coordinate just above the lower hull. The box edges are also plotted. The lower hull is plotted as 20 circumferential x cross-sections and 8 longitudinal curves at equally spaced polar angles about the lower hull centerline. Hidden lines on the lower hull are removed while hidden lines on the strut and box are shown dashed. The hull may be shown from any viewpoint given by (R, PHI, THETA). PHI is the polar angle in x-y plane and THETA is the elevation angle above the x-y plane. The hull is plotted in the global coordinate system. Figure 3-4 shows a test hull plotted with this routine.

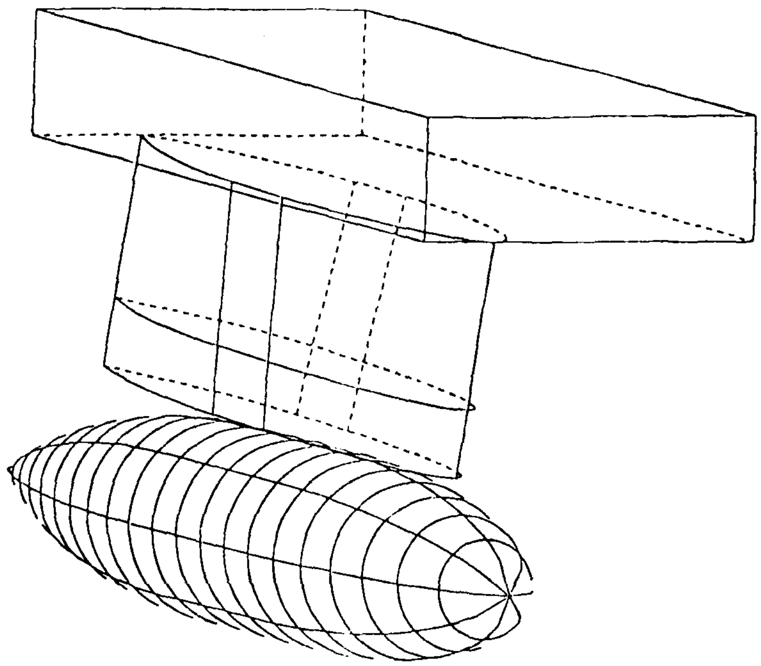


Figure 3-4. Unfaired Hull Plot.

4.0 SWGRID - HULL FAIRING AND SURFACE EQUATION ROUTINE

Given the initial geometry description of the strut and lower hull obtained from SWIN input, SWGRID produces a faired hull form below the box (see Figure 4-1). The general shape of the inboard and outboard fairing surfaces connecting the strut and lower hull is controlled by the fairing parameters input by the user in SWMOD. Default values for these parameters may be generated by the program if required. The actual fairing and surface grid construction is done automatically in SWGRID according to the given fairing parameters. In order to select the fairing parameters effectively the user should understand the fairing techniques as described in the remainder of this section.

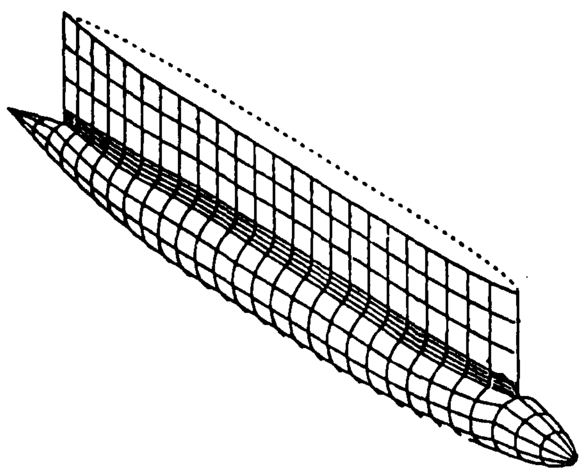


Figure 4-1. Three-dimensional view of hull.

The hull surface is defined piecewise using two parameter cubic spline patches. In constructing these surface patches, SWGRID requires knowledge of the hull surface at a distinct set of points. These points,

designated the nodal points, form the corners of the surface patches. In effect, the three-dimensional ship surface is mapped onto a region in the two-dimensional parameter space with spline functions.

4.1 Grid Parameterization

The ship surface (below the box) is defined mathematically as a function of two spline parameters, α and β. The equation for the ship surface is expressed in terms of the position vector, $\vec{R}$, as

$$\vec{R}(\alpha,\beta) = x(\alpha,\beta)\ \hat{i} + y(\alpha,\beta)\ \hat{j} + z(\alpha,\beta)\ \hat{k}\ .$$

The surface is divided into surface patches by lines of constant α and β values. The parameters are, in effect, surface coordinates. The α coordinate runs lengthwise along the ship, positive aft with $\alpha=0$ at the nose. The β coordinate runs around the girth of the ship, the positive direction being from inboard to outboard with $\beta=0$ on the keel.

On each patch the surface is represented as a function of the two parameters using Hermite cubic splines. The surface maps onto a cross-shaped grid in the α,β plane comprised of rectangular elements. At each nodal point on the grid (indexed i,j) the values α_i, β_j, $\vec{R}_{i,j}$, $(\frac{d\vec{R}}{d\alpha})_{i,j}$, $(\frac{d\vec{R}}{d\beta})_{i,j}$, and $(\frac{d^2\vec{R}}{d\alpha d\beta})_{i,j}$ are calculated and stored in the computer program. Now given an α,β position on the grid, one can calculate any desired surface quantity at the corresponding ship surface point using Hermite splines between the four surrounding grid points. A Hermite spline is a cubic spline which matches the function values and its derivative at the endpoints of a spline interval.

Figure 4-2a shows a grid in the α,β plane corresponding to a typical hull configuration. The surface position vector, $\vec{R}(\alpha,\beta)$, is a continuous function of the parameters α and β on the grid. The darkened

lines on the grid indicate discontinuities in the derivatives, $\vec{R}_\alpha$, $\vec{R}_\beta$ and $\vec{R}_{\alpha\beta}$. The darkened vertical lines correspond to the strut leading and trailing edges and indicate discontinuities in $\vec{R}_\alpha$ and $\vec{R}_{\alpha\beta}$. The darkened horizontal lines indicate discontinuities in the values $\vec{R}_\beta$ and $\vec{R}_{\alpha\beta}$. These lines divide the hull girth into six regions as shown in Figure 4-3. Girth regions 1 and 6 are the unmodified strut surfaces. Regions 2 and 5 are the inboard and outboard fairing surfaces and regions 3 and 4 correspond to the axisymmetric lower hull surface.

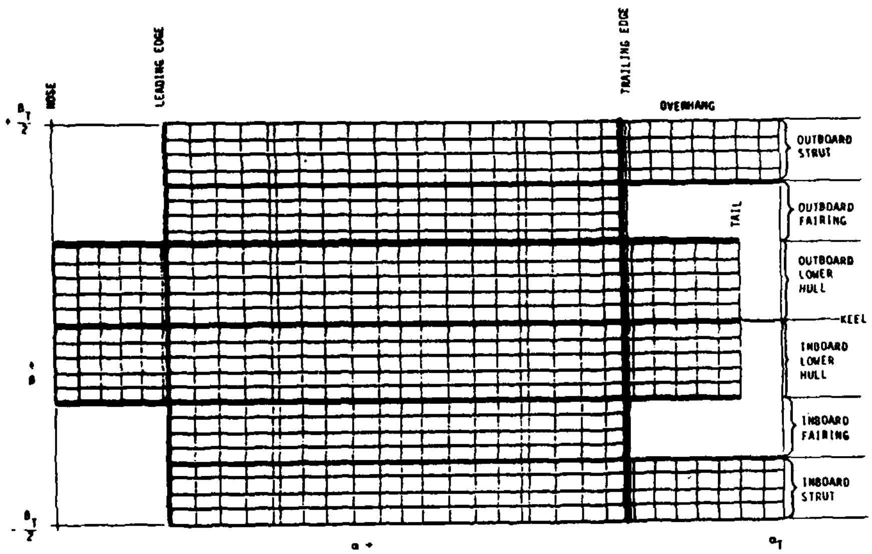


Figure 4-2. Coordinate Grid in the α-β Parameter Plane

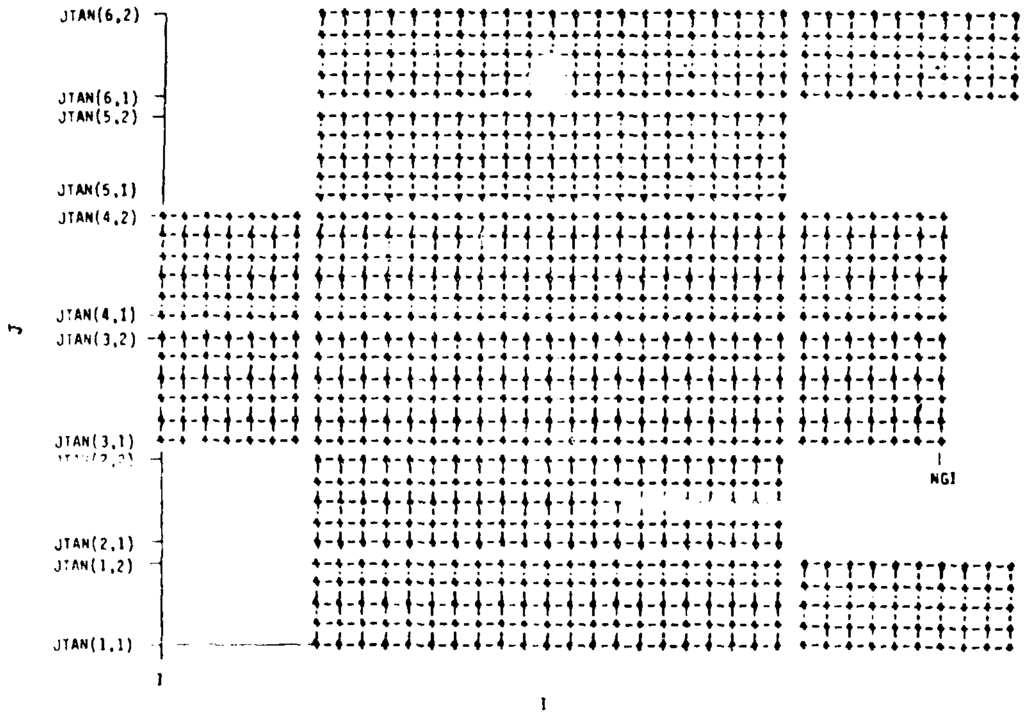


Figure 4-2b. Matrix representation of the surface grid.

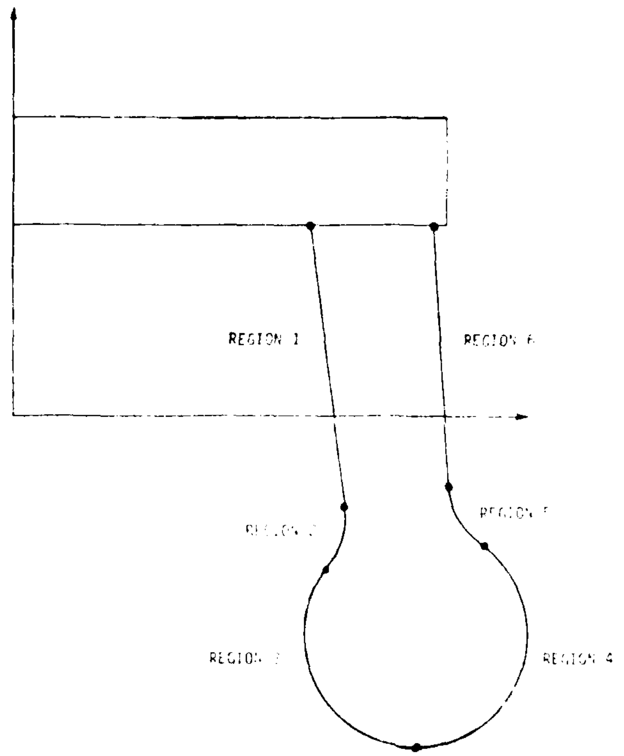


Figure 4-3. Girth Regions.

The derivatives, $\vec{R}_\alpha$ and $\vec{R}_\beta$, may be thought of as vectors tangent to the hull surface which point in the α and β directions respectively. The hull outward normal vector, $\hat{n}$, is given by

$$\hat{n} = \frac{\vec{R}_\beta \times \vec{R}_\alpha}{|\vec{R}_\beta \times \vec{R}_\alpha|} .$$

This vector is continuous everywhere on the hull except across portions of the inboard and outboard fairing-lower hull interface lines. Elsewhere on the grid, the vectors, $\vec{R}_\alpha$ and $\vec{R}_\beta$, may be discontinuous but the normal vector, $\hat{n}$, remains continuous. This allows the grid lines to change their direction in the hull surface while maintaining surface smoothness.

The computer stores the grid values in an array form. Figure 4-2b depicts the array form of the grid in Figure 4-2a. The I index corresponds to the α nodes, while the J index corresponds to the β

Method 3:
- Canted struts only
- Constant outboard mid-section fairing radius
- Strut lines used as outboard mid-section fairing region boundaries must clear the lower hull surface

All three methods construct a mid-section region and two transition regions in the same manner as the inboard fairing method. The outboard mid-section boundaries XOF and XOA are set in SWMOD as fractions of total strut length.

Outboard Fairing Method 1

Outboard Fairing Method 1 is identical to the inboard fairing method except that the fairing arcs curve in the opposite direction. The mid-section fairing curves are constructed with routine F6 using a constant fairing radius ROF set in SWMOD. A typical mid-section fairing section is shown in Figure 4-16. If the lower hull centerline lies in the strut centerplane and ROF and RIF are set equal, then the resulting inboard and outboard fairing surfaces will be mirror images of each other.

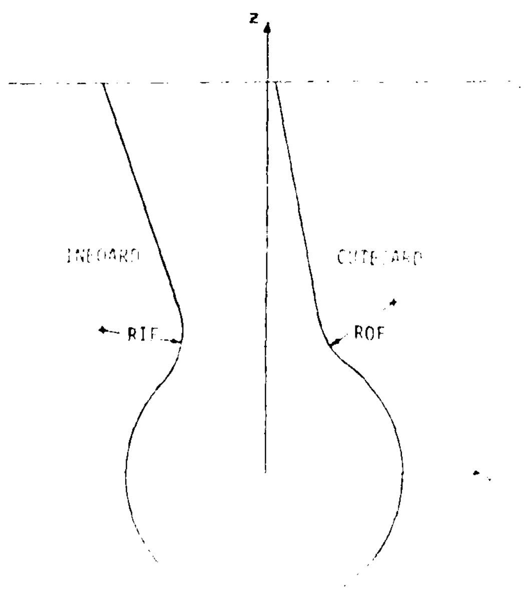


Figure 4-16. Example fairing section for outboard fairing method 1.

The inboard fairing surface consists of a mid-section region and two transition regions. The mid-section region consists of fairing curves constructed using fairing routine F6 (Figure 4-10) with a constant fairing radius RIF at all sections.

RIF is set by the user in SWMOD. The extent of the mid-section region is also set in SWMOD with the parameters XIF and XIA. The parameters set the distance of the fore and aft mid-section boundaries from the leading and trailing edges respectively. The values are given as fractions of total strut length between zero and one. A small value gives a small transition region, while a large value results in a large transition region. As a default condition, the program uses the mid-section borders (Figure 2-1) as the boundary lines.

The transition region fairing curves form smooth transition regions between the mid-section boundaries and the leading and trailing edges. Fairing routine F8 is used to construct these curves. The values of DR and A_0 are varied between the mid-section boundary values and the leading and trailing edges. DR varies linearly and A_0 varies elliptically.

4.3.4 Outboard fairing methods

Three methods are used to construct the outboard fairing curves allowing the fairing of a large array of possible hull configurations. Each method uses a different subset of the nine construction routines F1 through F9. The outboard fairing method is chosen in SWMOD to suit a particular hull configuration.

Method 1: • Vertical or canted struts aligned with the lower hull

Method 2: • Canted struts only
• Variable outboard mid-section fairing radius

Method 2 (F9) constructs a fairing arc from the point s to a y position on the lower hull given by the user. Method 3 (F1) constructs an arc from the point s to a vertical intersection with the z = 0 plane (Figure 4-5, $A_0 = 0$, $z_0 = 0$). The arc is truncated at the intersection with the lower hull surface at point p.

Method 1 should give consistently good fairing curves. Method 2 allows more complete control over these fairing curves and should be useful for modifying curves obtained using method 1. LE/TE method 3 may be useful in connection with hulls faired using "Outboard Fairing Method 2" (Section 4.3.4).

4.3.3 Inboard fairing method

A single method is used to construct the inboard fairing curves for all strut-lower hull configurations. The type of surface formed using this method is shown in Figure 4-14.

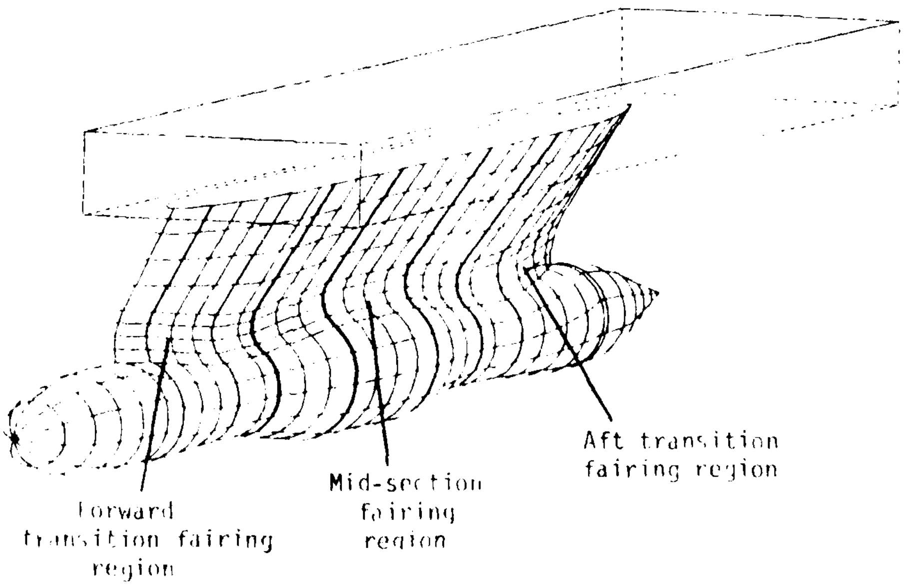


Figure 4-14. Three-dimensional view of inboard hull with mid-section and transition regions marked.

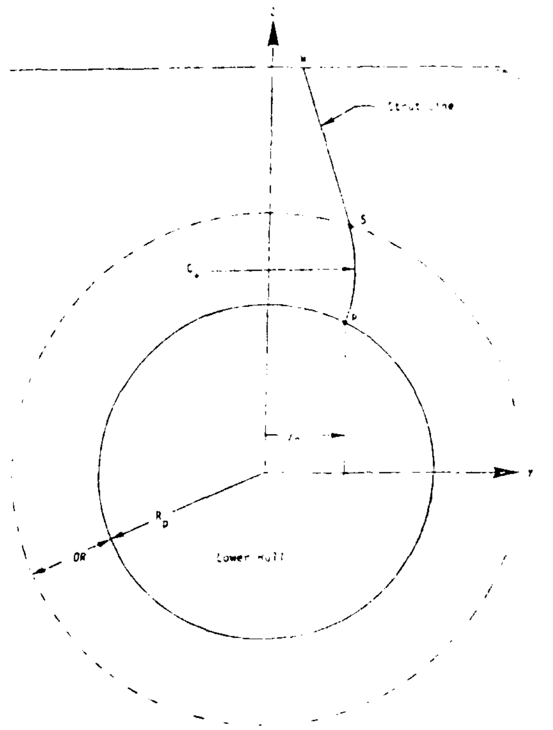


Figure 4-13. F9 Fairing Construction.

4.3.2 Leading edge/trailing edge (LE/TE) fairing methods

The leading and trailing edge fairing curves are constructed using a single arc from the strut edge to the lower hull surface. There are three LE/TE methods for controlling the shapes of these curves. These LE/TE curve shapes also affect the inboard and outboard fairing surfaces as discussed in Sections 4.3.3 and 4.3.4.

The three LE/TE fairing methods use routines F7, F9 and F1 respectively. The parameter DR is required input for all three methods. DR is the radial distance from the lower hull surface at which to locate point s. Method 1 (F7) constructs a fairing arc from point s to an intersection point p perpendicular to the lower hull surface (Figure 4-11).

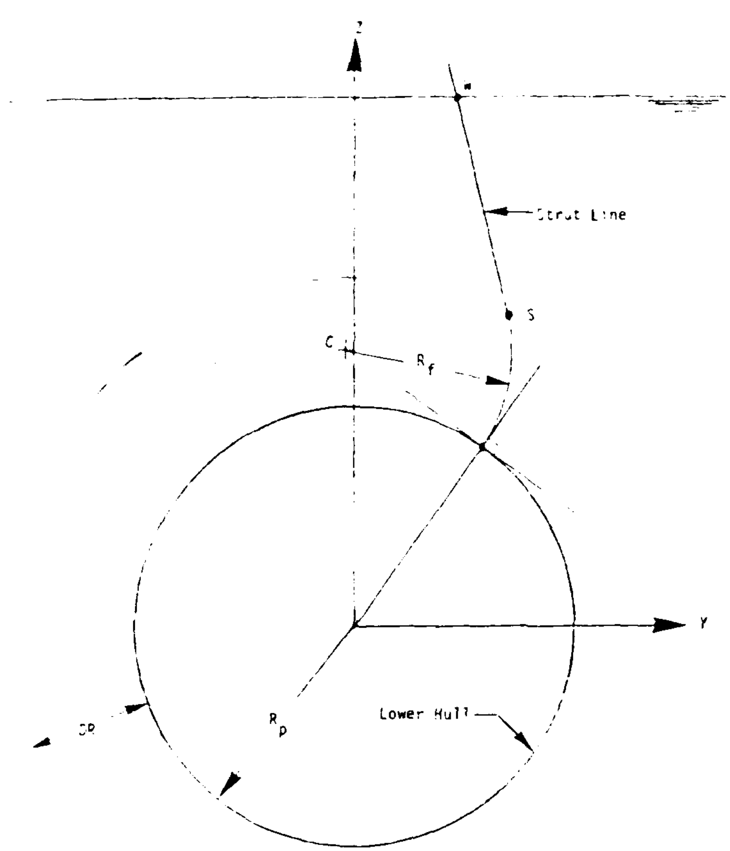


Figure 4-11. F7 Fairing Construction

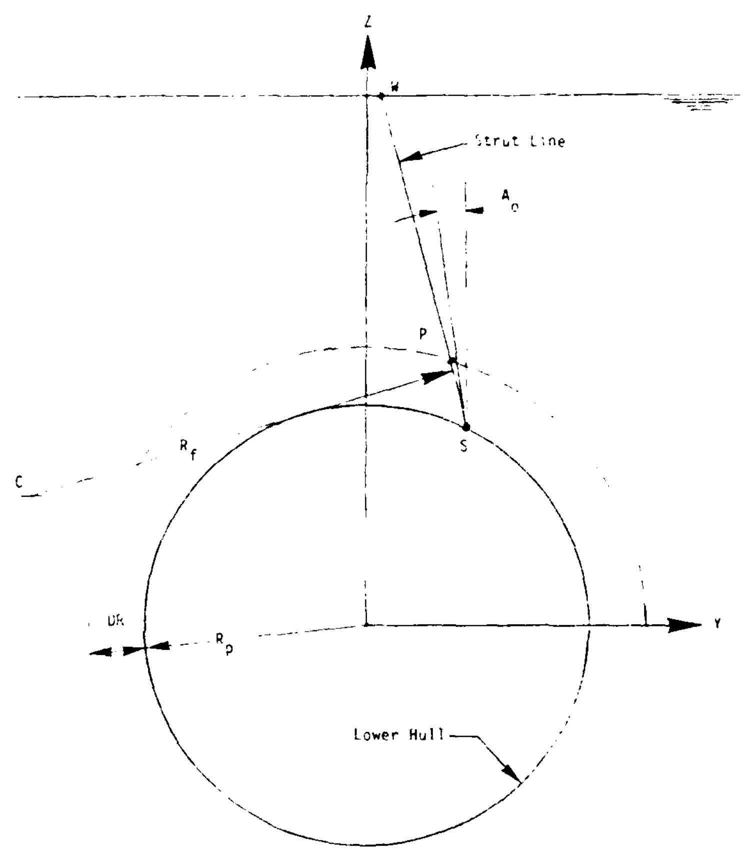


Figure 4-12. F8 Fairing Construction

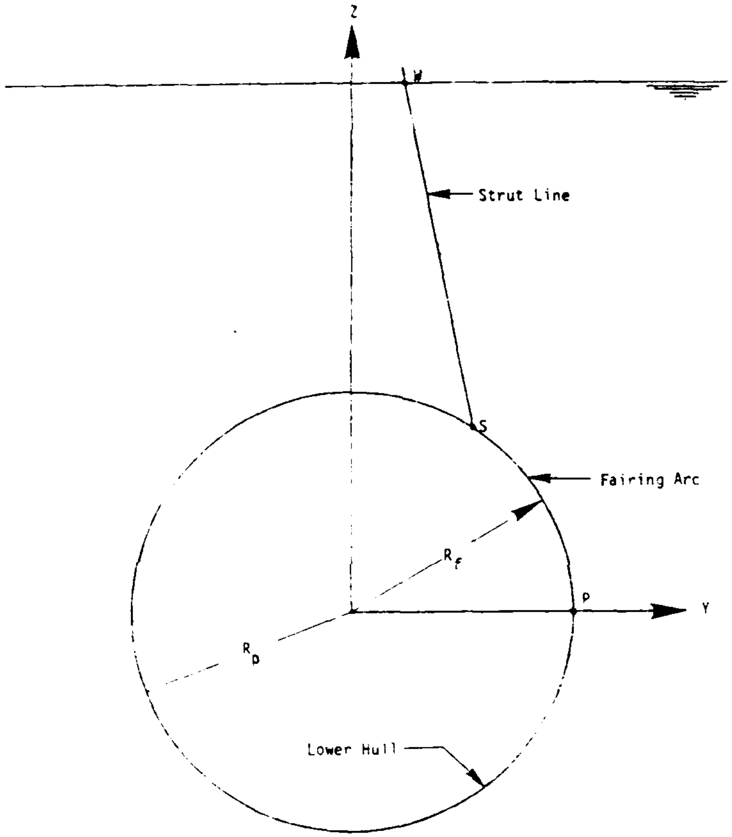


Figure 4-9. F5 Fairing Construction

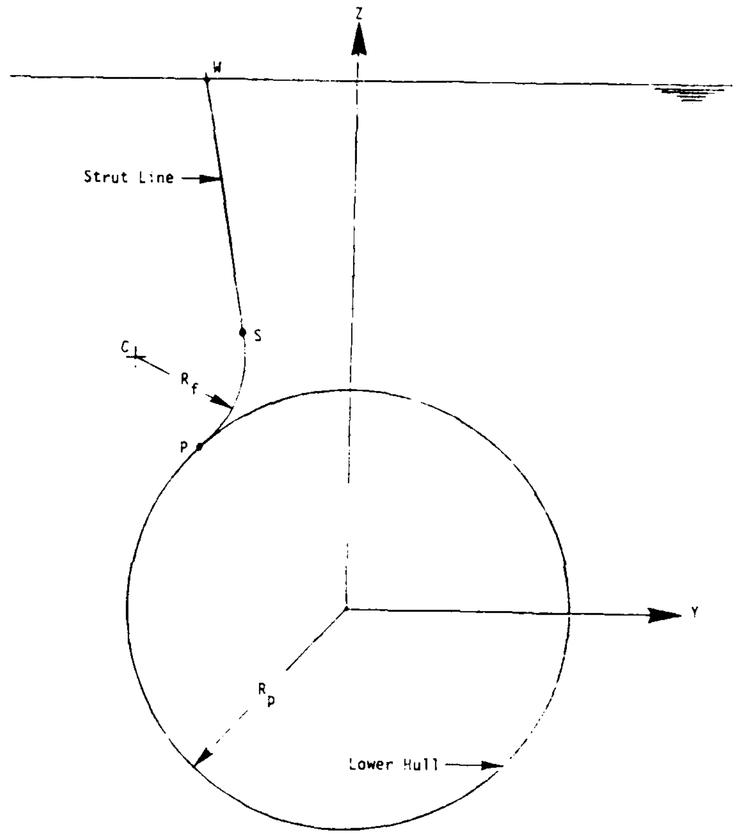


Figure 4-10. F6 Fairing Construction

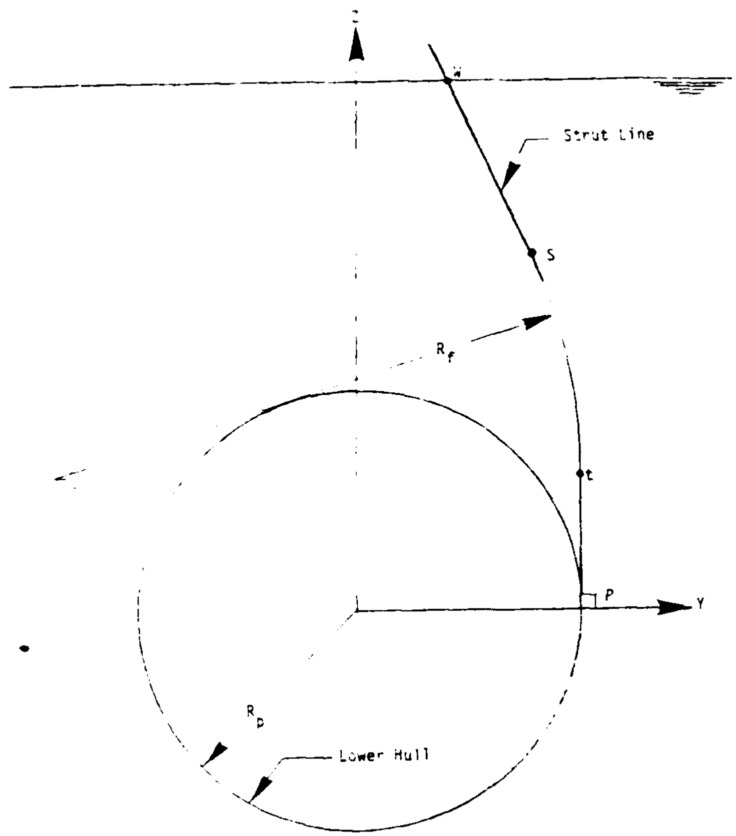


Figure 4-7. F3 Fairing Construction

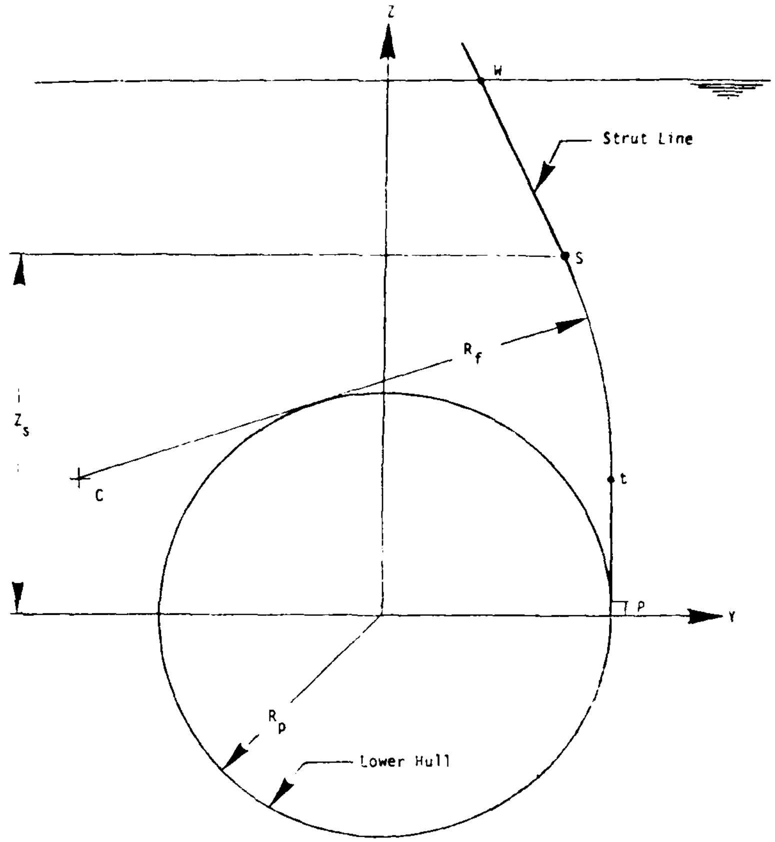


Figure 4-8. F4 Fairing Construction

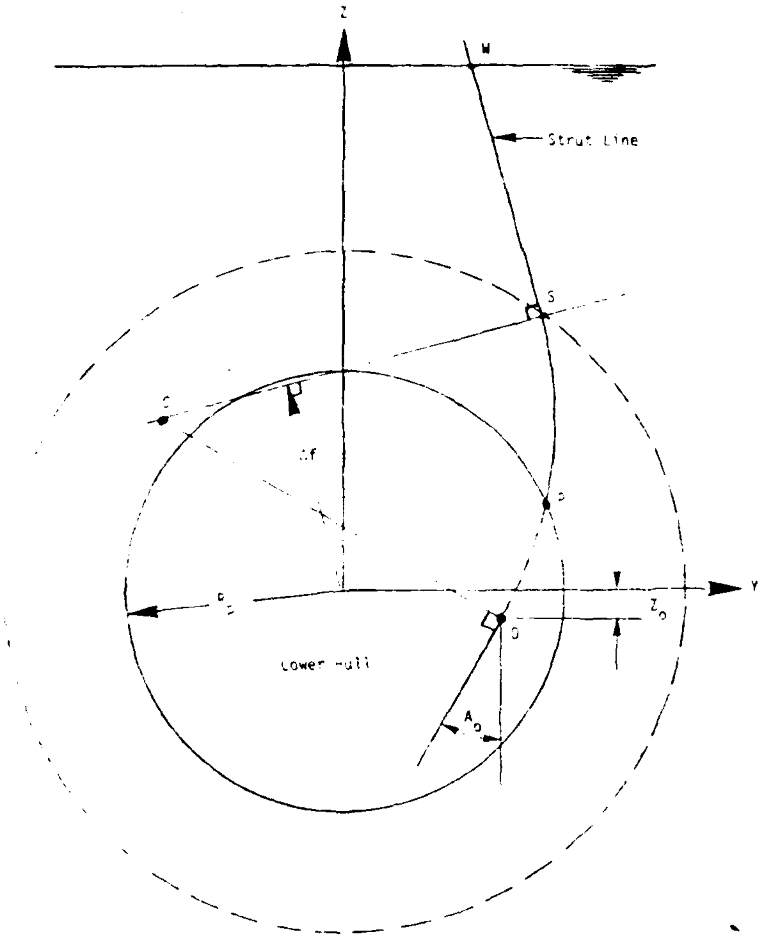


Figure 4-5. F1 Fairing Construction

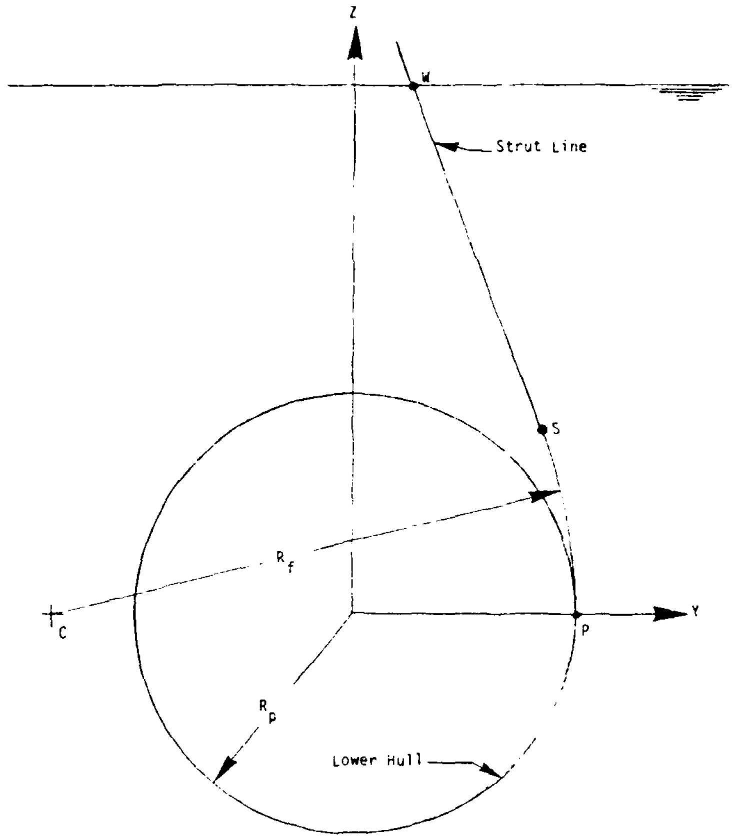


Figure 4-6. F2 Fairing Construction

F2 Given: Point p on the lower hull side at z = 0

Fairing: Arc $\widehat{ps}$ is constructed with ps tangent to the lower hull at p. R_f is variable.

F3 Given: Parameter z_s

Fairing: Arc $\widehat{st}$ is drawn with a vertical tangent at t. The vertical line segment $\overline{tp}$ completes the fairing. R_f is variable.

F4 Given: Fairing radius R_f

Fairing: Arc $\widehat{st}$ is drawn with a vertical tangent at t. The vertical line segment $\overline{tp}$ completes the fairing.

F5 Given: The strut line intersects the lower hull surface at point s

Fairing: Arc $\widehat{sp}$ is drawn identical to lower hull surface. $R_f = R_p$.

F6 Given: Fairing radius R_f

Fairing: Arc $\widehat{sp}$ is drawn tangent to the lower hull at point p.

F7 Given: Parameter DR

Fairing: Arc $\widehat{sp}$ is drawn tangent to the lower hull normal at point p. Point s is a distance R_p + DR from the origin (lower hull centerline).

F8 Given: Parameters A_0, DR

Fairing: Arc $\widehat{sp}$ is drawn with a tangent line angled A_0 from the vertical at point p. Point s is a distance R_p + DR from the origin.

F9 Given: Parameters y_H, DR

Fairing: Arc $\widehat{sp}$ is drawn with point p at $y = y_H$. Point s is a distance R_p + DR from the vertical

Note: All fairing curves are tangent to the strut line at point s except F5.

4.3.1 Construction of the fairing curves

The fairing curves are constructed using circular arcs and straight line segments in combination. Two fairing curves are constructed at each lower hull section (inboard and outboard) to form the fairing cross sections. Fairing curves are constructed in the lower hull local coordinate system (Appendix A) so that x cross-sections of the lower hull appear as circles. The general algorithm used to construct a fairing curve is as follows.

(1) All fairing curves, when shown projected in the x-z plane, appear as straight lines (see Figure 4-4). Thus, the x-z fairing equation has the form $x = az + x_0$.

(2) The fairing curves are constructed in the y-z plane. The program selects a line in one of the strut planes and a circular x cross-section of the lower hull. It then constructs a fairing curve between the two using either a circular arc or an arc-line segment combination.

(3) An iterative process is used to ensure that the strut line and lower hull section match according to step 1.

The nine fairing curve construction routines are shown in Figures 4-5 through 4-13. A short description of each routine follows.

<u>F1</u> Given: Parameters z_0, A_0, Δf (or DR)

Fairing: Point s is defined by Δf or DR. Arc $\widehat{so}$ is drawn with point o on $z = z_0$ and tangency angle, A_0, from the vertical. The arc is truncated at point p or continued to the lower hull surface with a straight line segment if point o lies outside the lower hull, R_f is variable.

(5) The grid values of $\vec{R}(I,J)$ and $\vec{R}_\beta$ are calculated from the known geometry of these sections.

(6) The values of $\alpha(I)$ corresponding to each of the fairing sections are set approximately to arc length along the lower hull surface from $\alpha(1) = 0$ to $\alpha(NGI) = \alpha_T$.

(7) The grid values of $\vec{R}_\alpha(I,J)$ and $\vec{R}_{\alpha\beta}(I,J)$ are calculated using three point differentiation between adjacent sections.

(8) The grid values $\vec{R}$, $\vec{R}_\alpha$, $\vec{R}_\beta$ and $\vec{R}_{\alpha\beta}$ are transformed to the global coordinate system.

The hull surface is now completely defined as a function of the parameters α and β in the global coordinate system.

4.3 Fairing Methods

There are nine elemental fairing construction routines, F1-F9. These routines construct the individual fairing curves connecting the strut to the lower hull. To produce smooth inboard and outboard fairing surfaces, the fairing curves must vary from section to section along the hull in a systematic way. There are three "outboard fairing method" available for directing the construction of the outboard fairing surface. A single "inboard fairing method" is used to direct the construction of the inboard fairing surface. The shape of the leading and trailing edge fairing curves is controlled separately using one of three "LE/TE fairing methods." The outboard fairing method and the LE/TE fairing method are chosen by the user in SWMOD to suit a particular hull.

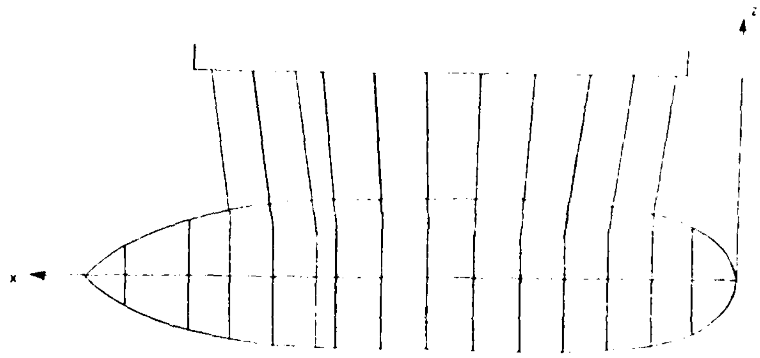


Figure 4-4b. Grid construction - Step 3.

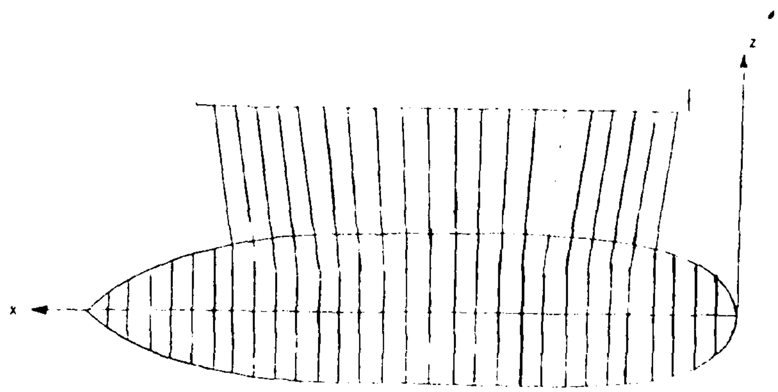


Figure 4-4c. Grid const ̈ction - Step 4.

values define the interiors of the spline patches. The algorithm used to construct the grid is as follows.

(1) The values of $\beta(J)$ are set from $\beta(1) = -\beta_T/2$ to $\beta(NGJ) = +\beta_T/2$ where β_T is the estimated arc length around the hull girth at midship. β values are uniformly spaced on each of the six girth regions.

(2) Four fairing sections are constructed from lines in the strut to the lower hull surface as shown in Figure 4-4a. The four lines in the strut are the leading and trailing edges and the fore and aft mid-section borders.

(3) Additional fairing sections are constructed to intersect the lower hull at the knots of the hull radial distribution spline as shown in Figure 4-4b.

(4) Extra fairing sections are added (if needed) so that the maximum distance between fairing sections is approximately 1/30 the lower hull length (see Figure 4-4b). Grid divisions are also added in front of the leading edge and aft of the trailing edge.

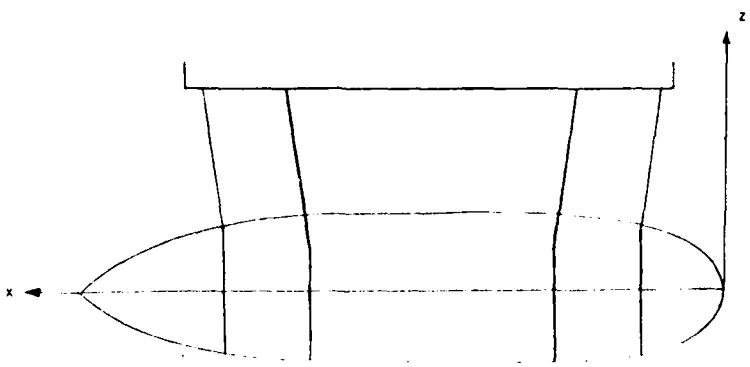


Figure 4-4a. Grid construction - Step 2.

nodes. The blanked out regions in Figure 4-2b correspond to the darkened lines in Figure 4-2a. The grid surface is not defined in these blank regions. The program uses two I indices to store double values of $\vec{R}_\alpha$ and $\vec{R}_{\alpha\beta}$ at a single point $\vec{R}$ on the surface. Similarly, two J indices are used to store double values of $\vec{R}_\beta$ and $\vec{R}_{\alpha\beta}$. The I and J indices are set automatically in the program. J varies from 1 to NGJ (NGJ $\approx$ 30) where NGJ depends on the hull girth dimensions. The I index varies from 1 to some value NGI which depends on the particular hull configuration (NGI $\approx$ 35).

4.2 Grid Construction

The grid parameterization scheme as outlined in Section 4.1 requires the values of $\alpha(I)$, $\beta(J)$, $\vec{R}(I,J)$, $\vec{R}_\alpha(I,J)$, $\vec{R}_\beta(I,J)$ and $\vec{R}_{\alpha\beta}(I,J)$ for each I,J node on the grid. The SWGRID routine calculates these values in two steps. The program first constructs a set of faired curves which wrap the girth at positions along the hull (see Figure 4-3). These fairing sections follow the x-z slopes of the three strut section borders in the girth regions 1, 2, 5 and 6 and run roughly perpendicular to the lower hull centerline in regions 3 and 4. Generally they are not constant x cross-sections but correspond to lines of constant $\alpha(\beta = -\beta_T/2$ to $+\beta_T/2)$ on the α,β grid. The grid point values, $\vec{R}(I,J)$, are taken off these curves. The points are positioned in equal arc length increments on each of the six girth regions. The values of $\vec{R}_\beta(I,J)$ are also calculated at these points from the section geometry. With the $\vec{R}$ and $\vec{R}_\beta$ values determined, the constant curves are now defined in terms of Hermite spline function of β.

The second step is to calculate the values of $\vec{R}_\alpha$ and $\vec{R}_{\alpha\beta}$ at the grid nodal points. These values are calculated using three point differentiation between adjacent sections. The $\vec{R}$ and $\vec{R}_\alpha$ values define the constant β curves running longitudinally on the hull in terms of Hermite splines in α. On the lower hull and strut surfaces the $\vec{R}_\alpha$ values are adjusted so as to match the known surface normals at the grid points exactly. The $\vec{R}_{\alpha\beta}$

Outboard Fairing Method 2

Outboard Fairing Method 2 is to be used on inward canted struts only and produces a fairing surface like the one shown in Figure 4-17.

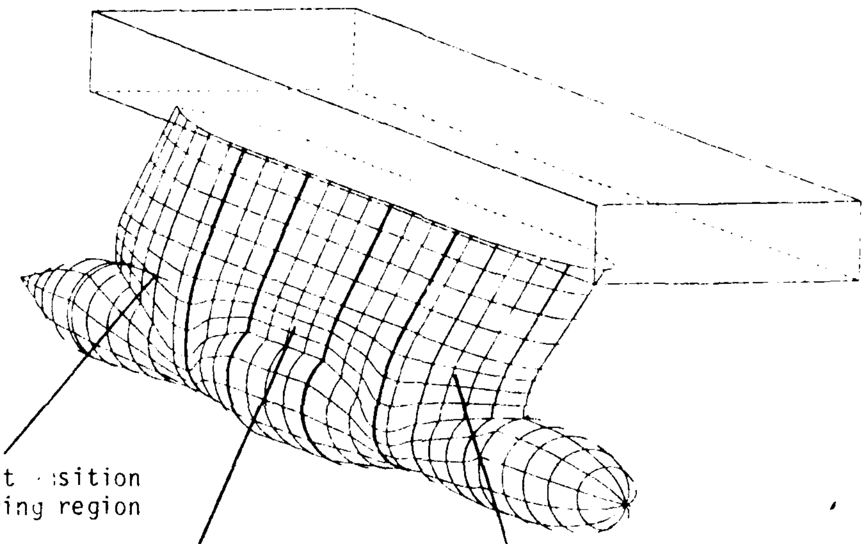


Figure 4-17. Outboard method 2 fairing surface.

Method 2 constructs the mid-section fairing curves using routines F1, F2 and F3. At each fairing section, one of the three routines is selected according to the strut-lower hull section configuration. Figure 4-18 shows the three constructions as they would be used at different fairing sections. Curves of these types form a smooth fairing surface when splined together.

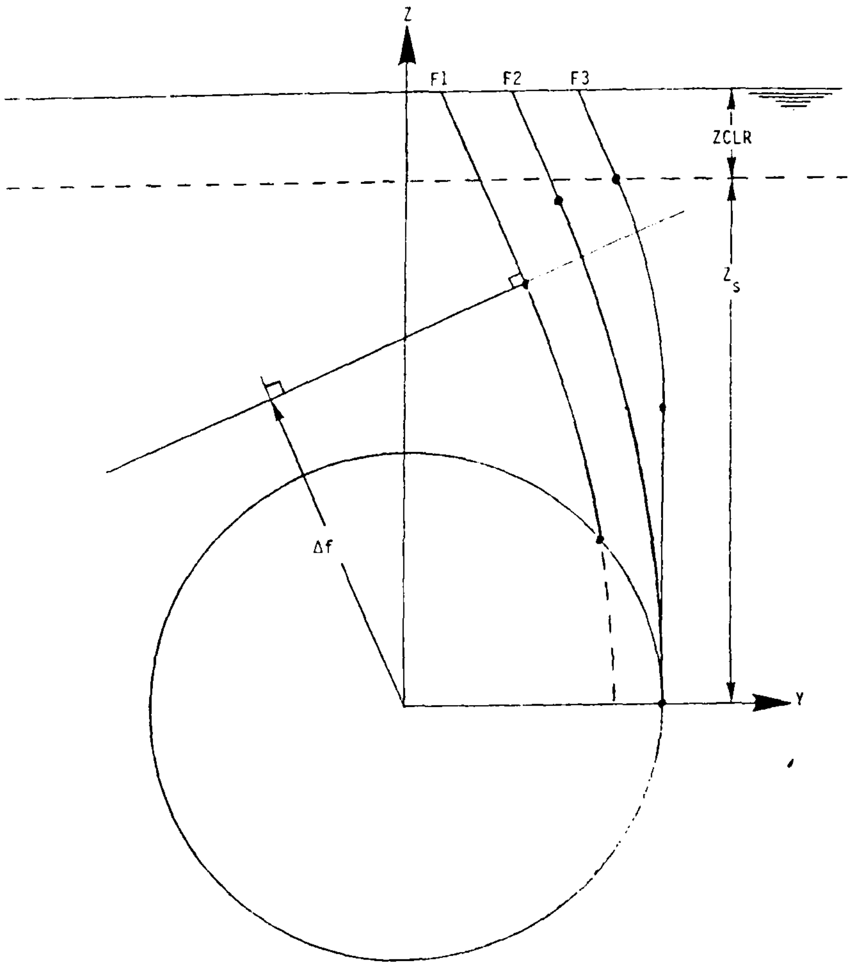


Figure 4-18. Examples of fairing curves for outboard fairing method 2.

The automatic process used in selecting one of the three constructions is as follows.

Given: Strut line, lower hull section, Δf, ZCLR

The value of Δf is a function of the values DR(LE) and DR(TE). Δf is calculated for the leading and trailing edge fairing

sections and varied linearly for the hull sections in between.

Step 1: The program attempts to fit an F1 type fairing curve with $z_o = A_o = o$ (see Figure 4-5). If point p exists, the fairing curve is complete.

Step 2: If step 1 fails (point o outside lower hull) then an F2 type curve is constructed. If point s lies below the ZCLR line, the fairing is complete.

Step 3: If step 2 fails (point s above the ZCLR line) then a F3 type curve is fit the Z_s set to ZCLR.

The method 2 transition fairing curves are constructed using the same three routines (F1, F2 and F3) used for the mid-section curves. The parameters Δf, z_o and A_o are varied from the mid-section boundary sections to the leading and trailing edge sections, Δf linearly and z_o and A_o elliptically.

Outboard Fairing Method 3

This method produces a fairing surface similar to that of method 2. Figure 4-19 shows a typical hull faired with method 3.

The mid-section fairing curves are constructed using a constant fairing radius ROF where possible (ROF set in SWMOD). These curves are constructed using four routines, F5, F2, F4 and F3. Figure 4-20 shows how these four constructions would be used at different hull fairing sections.

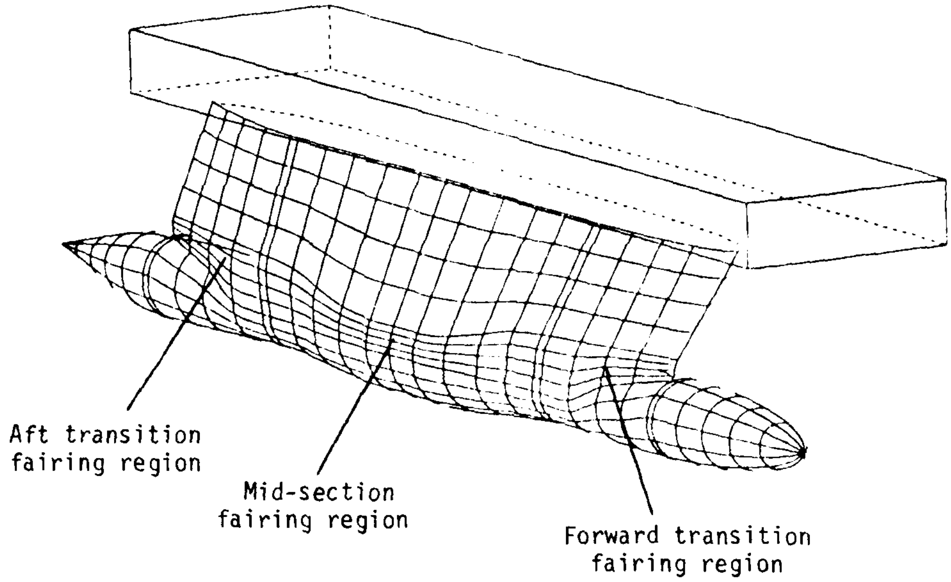


Figure 4-19. *Outboard method 3 fairing surface.*

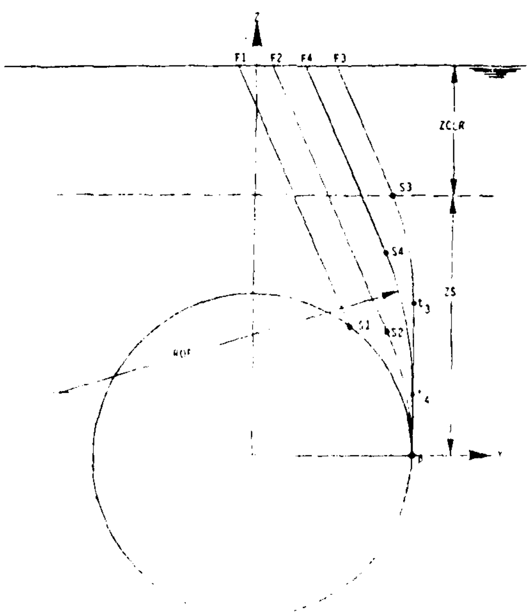


Figure 4-20. Examples of fairing curves for outboard fairing method 3.

The automatic process used in selecting the proper construction at a given section is as follows.

Step 1: F4 is used to construct an arc with radius ROF (constant at all mid-sections) from the strut to a point t_3 lying on the vertical tangent to the lower hull side. If this point is above the y axis, the fairing curve is completed with the straight line segment $\overline{t_4p}$.

Step 2: If the point s_4 from step 1 lies above the ZCLR line then construction F3 is used. An arc of radius R_f ($R_f < R_0$) is constructed from a point s_3 lying on the ZCLR line to a point t_3 directly above the lower hull side. The straight line segment $\overline{t_3p}$ is used to finish the fairing curve.

Step 3: The F2 construction is used if the point t_4 from step 1 lies below the y axis. An arc radius of R_f less than R_0 is constructed from the point p to the strut line. The arc is tangent to the lower hull surface at p.

Step 4: Routine F5 is used if the strut line intersects the lower hull section. In this construction the arc s_5p is considered the fairing curve for the grid construction.

The method 3 transition fairing curves are constructed using routines F1 and F3. The parameters Δf, z_0 and A_0 are again varied from the mid-section boundaries to the leading and trailing edges, Δf linearly and z_0 and A_0 elliptically.

4.4 Fairing Method Suggestions

4.4.1 Horizontal upper fairing line

The outboard fairing strut tangency line may be made horizontal in some cases using outboard fairing methods 2 and 3 (not method 1). Set ZCLR to the desired maximum fairing level. Set DR(LE) and DR(TE) to large values. For IFTYP = 3 also set ROF to a large value. This will force point s in Figures 4-5, 4-7, 4-11, 4-12 and 4-13 to be located at the highest allowable point, z = ZCLR.

4.4.2 Error messages

The program may be used to construct a particular fairing section according to the given fairing parameters and hull configuration. The program will issue an error message describing the problem and suggesting a possible solution. The program will then return to SWMOD in the design loop where the user may modify the fairing parameters and/or hull configuration. The plotting routine SWMOD may often aid the user in further diagnosing errors.

5.0 SWPROP - HULL PROPERTIES CALCULATIONS

This routine calculates many descriptive quantities related to the hull surface produced by SWGRID. The quantities include the displaced volume, center of buoyancy, surface area, maximum draft and maximum beam.

The calculations of the area, volume and buoyancy center are done by four-point Gaussian quadratic integration of the surface equation over the portion of the α,β grid surface below the waterline. The surface integrals are given as:

$$\text{Area} = \iint dS \tag{5-1}$$

$$V = 1/3 \iint \vec{R} \cdot \hat{n} \, dS \tag{5-2}$$

$$CB_x = \frac{1}{2V} \iint x^2 n_x \, dS \tag{5-3}$$

$$CB_y = \frac{1}{2V} \iint y^2 n_y \, dS \tag{5-4}$$

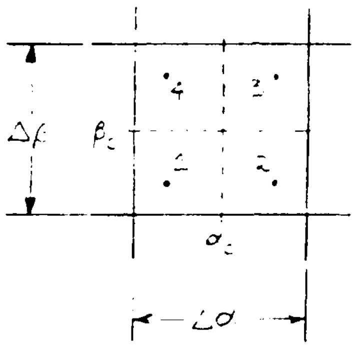
$$CB_z = \frac{1}{2V} \iint z^2 n_z \, dS \tag{5-5}$$

where the integrals are carried out over the entire hull surface. The equation for the volume and buoyancy center were derived from volume integrals using the Gauss divergence theorem.

The integration is carried out on the α,β grid constructed in SWGRID. In this coordinate system the incremental area dS is given as

$$dS = |\vec{R}_\beta \times \vec{R}_\alpha| \, d_\alpha \, d_\beta$$

where $\vec{R}_\beta$ and $\vec{R}_\alpha$ are the partial derivatives of the position vector R with respect to the β and α parameters respectively. Four-point Gaussian quadrature is applied to each rectangular panel on the grid. The quadrature rule uses four points on each grid rectangle as shown in Figure 5-1.



$$\alpha_i = \alpha_c \pm \tfrac{1}{2}\frac{\Delta\alpha}{3}, \quad i = 1,4$$

$$\beta_i = \beta_c \pm \tfrac{1}{2}\frac{\Delta\beta}{3}, \quad i = 1,4$$

Figure 5-1. Gaussian quadrature points on an α-β grid square.

The integrations in equations 5-1 through 5-5 are replaced by summations to give

$$\text{Area} = \sum_{\text{panels}} \Delta\alpha\Delta\beta \sum_{k=1}^{4} \omega_k \, |R_\beta \times R_\alpha|_k \tag{5-6}$$

$$V = 1/3 \sum_{\text{panels}} \Delta\alpha\Delta\beta \sum_{k=1}^{4} \omega_k R_k \cdot (R_\beta \times R_\alpha)_k \tag{5-7}$$

$$CB_x = \frac{1}{2V} \sum_{\text{panels}} \Delta\alpha\Delta\beta \sum_{k=1}^{4} \omega_k x_k^2 \; i \cdot (R_\beta \times R_\alpha)_k \tag{5-8}$$

$$CB_y = \frac{1}{2V} \sum_{\text{panels}} \Delta\alpha\Delta\beta \sum_{k=1}^{4} \omega_k y_k^2 \; j \cdot (R_\beta \times R_\alpha)_k \tag{5-9}$$

$$CB_z = \frac{1}{2V} \sum_{\text{panels}} \Delta\alpha\Delta\beta \sum_{k=1}^{4} \omega_k z_k^2 \; k \cdot (R_\beta \times R_\alpha)_k \tag{5-10}$$

The first summation on the above equations is carried out over all the panels on the α,β grid (see Figure 4-2a). The weighting factor, ω_k, is a constant value. $\omega = \frac{1}{4}$ for this quadrature rule. This calculation is quite accurate for the types of surfaces considered. Sample calculations

for a ship with NA = 30 panels lengthwise give estimates for the error in the volume, area and CB at

$$\varepsilon_V \approx 0.1\%$$

$$\varepsilon_A \approx 0.1\%$$

$$\varepsilon_{CB} \approx 0.01\% \text{ of the relevant } (x,y,z) \text{ hull dimension}$$

This calculation takes approximately 20 seconds CPU on a VAX 11/780 for a typical ship with 1000 panels and the time is linearly proportional to the number of panels.

The lower hull volume is calculated to be the volume of the unfaired axisymmetric lower hull. The calculation is done by an exact integration of the spline function for the lower hull radial distribution. The strut volume is calculated as the difference between the total hull volume and the lower hull volume.

The lower hull surface is considered to be all those panels below the center of the fairing inboard and outboard. The strut area is then all the panels above this line.

For the calculation of waterplane properties, the design waterline is found at approximately 300 points over its length, evenly spaced in the parameter α. Then the waterplane is interpolated onto 150 points evenly spaced in X, using linear interpolation. The area and moments are then found by integrating the waterplane using a simple rectangular approximation.

6.0 OUTPUT ROUTINES: SWPRNT, SWPLOT, SWOUT AND PANTHN

6.1 SWRINT - Lower Hull Descriptive Printout

This routine provides descriptive output for the hull form produced in the design loop. The user selects the file name for the output ("TTY" for terminal). The following output is given:

(1) All parameters (volume, area, CB, etc.) as calculated in SWPROP.

(2) Fairing parameters selected in SWMOD.

(3) Fairing radii and fairing construction routine used for each inboard and outboard fairing curve.

(4) Lower hull radii given at the breakpoints used by the spline representation and the original input lower hull description.

(5) Grid nodal point coordinates (strut local coordinate system).

Points with discontinuous surface normals in the β direction are marked with a "***" in the output. This output should prove useful in evaluating the faired hull forms and as a guide for modifications in SWMOD and provides documentation of the final hull form.

6.2 SWPLOT - Lower Hull Plotting Routines

SWPLOT allows the user to view the hull with four plotting routines:

PLTALL:	3-D plots of the hull surface
PSEC:	2-D plots of the alpha-constant grid lines
PX:	2-D plots of x cross-section cuts through the hull surface
PZ:	2-D plots of z cross-section cuts through the hull surface

PLTALL

This routine plots the constant [illegible] and [illegible] lines lying in the hull surface as shown in Figure 6-1. The user must input a viewpoint for the plot given by (RV, PHI, THETA). RV is the viewer distance from the origin (strut coordinate system). THETA is the polar angle (degrees) measured in the x-y plane. PHI is the elevation angle measured from the x-y plane (see Figure 6-1).

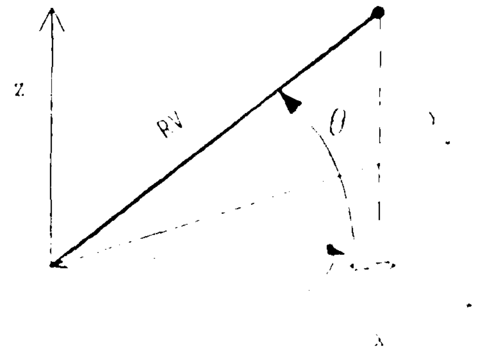


Figure 6-1. Viewpoint position given by (RV, PHI, THETA).

RV governs the effect of distance and allows the user to "zoom in" on the hull. If the user gives RV = 0, RV will be set to some large value so that a pure projection of the hull will be obtained.

A simple method is used to delete hidden lines on the plot which works well for most viewpoints of the hull. The outward surface normal, n, is calculated at each hull point to be plotted. The following dot product is calculated at each point:

$$DOT = \hat{n} \cdot (\vec{V} - \vec{r})$$

where $\vec{V}$ is the position of the viewpoint and $\vec{r}$ is the position vector on the hull. If DOT is greater than zero, then the surface is facing the viewer at this point and the point is plotted. If DOT is negative, the point is hidden and not plotted. This method will delete all hidden lines for a body which has an inward surface curvature at all points (i.e., a sphere or ellipsoid). With more general bodies, points on the surface facing the viewer may still be hidden behind another section of the body. With a SWATH-type ship this method is quite effective for most viewpoints.

PSEC

This routine plots the constant alpha curves of the grid projected in the x-z plane. These plots show how the individual fairing curves very from section to section. The user inputs a range of I values to plot.

PX

The routine plots constant x-sections of the hull. These plots demonstrate the smoothness of the faired surface representation.

6.3 SWOUT - Geometry Output

SWOUT allows the user to save the various pieces of the geometry description so that they may be read later by SWIN. The output may be the entire geometry description in an SWCOMS file (see Appendix B for details), or "duplicate" files, containing the input for strut, box or lower hull. The duplicate files contain the data for any of the three inputs in the form required by the input routine. If a change is made to the geometry using SWMOD, the new data can be stored, even if the fairing is incomplete.

SWOUT has its own menu;

```
SWOUT MENU

  1) WRITE DUPLICATE FILE OF STRUT DATA
  2) WRITE DUPLICATE FILE OF BOX DATA
  3) WRITE DUPLICATE FILE OF LOWER HULL DATA
  4) 1,2,AND 3 IN SEQUENCE
  5) WRITE SWCOMS DATA FILE FOR EXISTING HULL

ENTER CHOICE 1-5, '6' TO PRINT SWOUT MENU, RETURN TO EXIT SWOUT
```

NOTE: All plots are given in the global coordinate system.

6.4 PANTHN - Thin Ship Panelization

This routine creates the input required by REPOW, the resistance and powering calculation routine. This consists of a set of quadrilateral and triangular panels representing the strut and line segments representing the lower hull.

Each panel or line segment is assigned a non-dimensional source strength. For the strut, according to thin-ship theory, this strength is

$$\frac{\sigma}{v} = \frac{dT/dx}{4\pi}$$

σ = source strength

v = ship speed

T = strut thickness

The strut panels are chosen based on the hull surface grid and the magnitude of the source strength derived from the [illegible] of the surface normals.

The source strength for the lower hull segments, for slender-body theory is

$$\frac{\sigma}{V} = \frac{dA/dx}{4\pi}$$

where A is the cross-sectional area.

In order to create a uniform distribution, the number of source panels per unit length is set proportional to $d\sigma/dx$ or d^2A/dx^2.

The effects of the interaction between the strut and lower hull are approximated by "closure" panels. Since the upper surface of the lower hull is covered by the strut, it can produce no wave resistance. The closure panels cover the top of the lower hull and cancel some of its wave resistance. The source strength for the closure panels is

$$\frac{\sigma}{V} = \frac{\hat{n}_x}{4\pi}$$

n_x = x-component of the unit normal.

When creating the panel data file, the user is asked for form factors for the strut and lower hull. The form factor multiplies the flat-plate viscous resistance coefficient in REPOW. Default values of 1.0 for the strut and 1.17 for the lower hull are available. To neglect any form factor allowance, the user should enter values of 1.0.

The panel geometry is written in the REPOW/OPTVOL coordinate system, shown in Appendix A.

8.0 OPTVOL LOWER HULL OPTIMIZATION

The general approach of OPTVOL is to tune the lower hulls to a specified set of surface-piercing struts in such a way that the free-surface waves generated by the lower hulls act to cancel out those free-surface waves generated by the struts. In other words, the lower hulls are not designed so that they produce the fewest possible waves, but are designed instead to generate a wave field which has the greatest posssible cancellation.

The first step in the optimization procedure is the use of REPOW for the generation of the wave spectral file due to the struts alone operating at the design speed. The OPTVOL code is then used in an interactive mode to quickly generate several lower hull forms, each representing the optimum for the set of constraints chosen by the user. Using SWATHGEN, the lower hulls are easily integrated into a fully defined SWATH ship and the user can use the geometry information and REPOW to help judge which is best for the requirements.

OPTVOL asks the user for the SWCOMS file containing the original SWATHGEN hull description and for the file containing the strut free-surface spectrum generated by REPOW. The user is then asked for the constraints on the optimization, detailed below. The optimal radii distribution is found and printed at the terminal and the user may reject it and begin OPTVOL again, or create a SWATHGEN lower hull "duplicate" file for the optimized lower hull. This duplicate file can be combined with the original SWCOMS file in SWATHGEN to create the complete, faired hull form.

This process is illustrated in Figure 8-1, which shows the flow of data among the three programs SWATHGEN, REPOW and OPTVOL. Appendix C demonstrates this cycle. A flow diagram for OPTVOL alone is shown in Figure 1-4.

7.6 OPTVOL Input Generation

REPOW option 3 creates the input required for the optimization program OPTVOL. This consists of a binary format data file containing the Kochin function $J(u)$, the function $\beta(u)$ and the wavenumbers, as defined in Section 7.3.1, for the strut alone. The user is only asked to enter a data file name. As in the resistance determination the program displays the progress of the calculation.

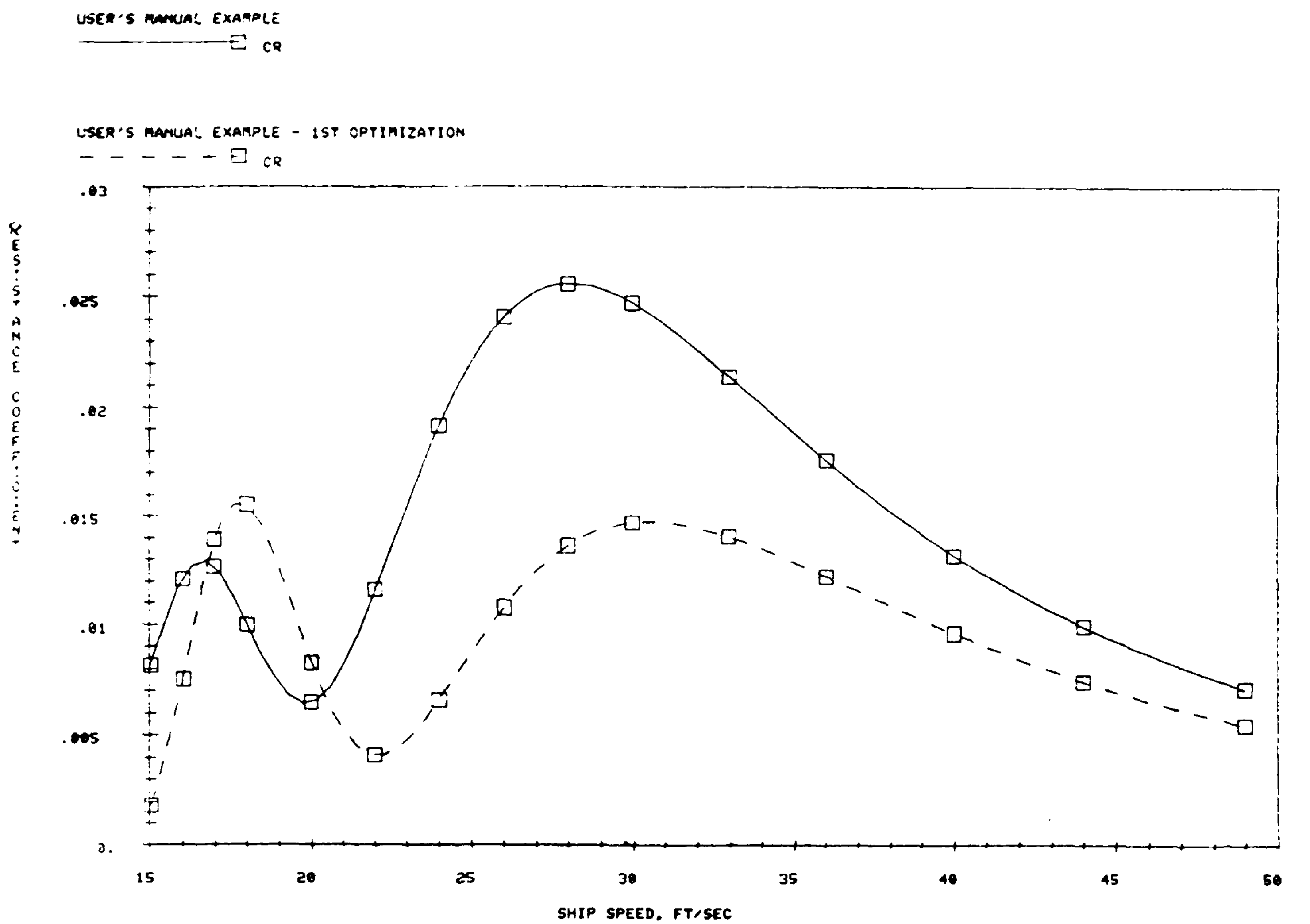


Figure 7-1. REPOW Plot Example.

A similar choice is required if resistance coefficients are plotted, although only five components are available:

```
FIVE CURVES ARE AVAILABLE:



   1) CT   - COEFFICENT OF TOTAL RESISTANCE
   2) CW   - COEFFICIENT OF WAVE RESISTANCE
   3) CF   - COEFFICIENT OF FRICTIONAL RESISTANCE
   4) CFS  - COEFFICIENT OF STRUT FRICTIONAL RESISTANCE
   5) CFH  - COEFFICIENT OF LOWER HULL FRICTIONAL RESISTANCE

ENTER YOUR CHOICES, AND ADD ZEROS FOR A TOTAL OF 5 ENTRIES:
```

After the curves have been specified, the user must set up the axes. The program prints out the minimums and maximums of the data to be plotted and asks the user to enter the minimum value on the axis, the maximum value, the "major tic" spacing, and the number of "minor tics" between major tics. The major tic spacing is the distance between numeric labels. The example plot, Figure 7-1 shows

XMIN = 15   XMAX = 50   TICMAJOR = 5   TICMINOR = 4.

This means that the distance between minor tic marks is 1.0 units.

The plots are drawn by connecting the data points with a cubic spline. The current data is plotted as solid lines and the compared data as dotted lines. The components are differentiated by the markers at the data points. A legend is provided at the head of the plot.

current run of REPOW, then the program requests only one "re-readable" data file for comparison. The user may choose to plot only the current data. If no resistance data has been generated, the program asks for two "re-readable" data files, though the user may plot only one set of data.

Once the data sets have been chosen, the user picks the quantities to be plotted. First the axes are chosen:

```
                 >>>> AXES MENU <<<<


     -- Y AXIS --                        -- X AXIS --
1) EFFECTIVE HORSEPOWER             1) SPEED IN FT/SEC
2) RESISTANCE IN POUNDS             2) SPEED IN KNOTS
3) RESISTANCE COEFFICIENTS          3) SPEED-LENGTH RATIO
                                    4) FROUDE NUMBER

     ENTER 2 CHOICES, ONE FOR EACH AXIS:
```

Then the components of each total quantity are chosen. For the EHP, only one component exists. For the resistance, the user may choose any combination of seven components. As noted below, seven values must be entered, even if only one component is desired

```
SEVEN CURVES ARE AVAILABLE:

   1) RT   - TOTAL RESISTANCE
   2) RW   - WAVE RESISTANCE
   3) RF   - FRICTIONAL RESISTANCE
   4) RFS  - STRUT FRICTIONAL RESISTANCE
   5) RFH  - LOWER HULL FRICTIONAL RESISTANCE
   6) RAPP - APPENDAGE RESISTANCE
   7) RCOR - CORRELATION RESISTANCE

ENTER YOUR CHOICES, AND ADD ZEROS FOR A TOTAL OF 7 ENTRIES:
```

7.3.3.3 Hull/Appendage Interference Drag

Treat the fin or rudder as intersecting with a flat wall. The resulting Hoerner expression for each fin and rudder is:

$$RHA = (0.75(t/c)^3 - 0.0003) \times (1/2)\ \rho\ V^2 \times c^2\ .$$

7.3.3.4 Wing Tip Drag

For lift coefficients close to zero, wing tip drag per edge can be represented by the following equation from Hoerner. It is applicable for each fin and rudder:

$$RTI = 0.075\ t^2 \times (1/2)\ \rho\ V^2\ . \qquad \text{(for blunt lateral edges)}$$

7.4 Resistance Data Output

Once resistance data is generated in REPOW, it can be saved for later examination. When option 6 in REPOW is chosen, the program requests data file names for the resistance data printout and for the "re-readable" resistance data file.

The printout may be directed to the terminal and an example is shown in Appendix C, pp. C-26 to C-29. It contains input data, calculated properties and the resistance data in tabular form.

The "re-readable" data file stores only the resistance data. This file can be read later by REPOW in option 5, resistance plots. In this way the data from two hulls can be compared.

7.5 Resistance Plots

When making plots of resistance, the program always allows two cases to be compared. If the user has already generated a data set in the

where

RP = Profile drag.
R_I = Induced drag.
R_{HA} = Hull/Appendage interference drag.
R_{TI} = Wing tip drag.

7.3.3.1 Profile Drag

This is composed of flat plate friction, resistance due to velocity augmentation and pressure resistance. For either the rudder or fin, the relevant equation from Hoerner is set out below:

$$RP = 2C_F\ (1 + 2\ (t/c) + 100\ (t/c)^4) * P * (\rho/2) * V^2$$

where C_F = ITTC line based on chord
P = Planform area of rudders or fins = S*C
V = ship speed
ρ = water density
c = input chord
t = input thickness
s = input span.

7.3.3.2 Induced Drag

It is assumed that the direction of local velocity induces an angle of 3^0 at the fins and rudders. Thus for each rudder and fin.

$$RI = (C_L^2/(0.9 \times \pi \times A)) \times (\rho/2) \times V^2 \times P$$

where C_L = lift coefficient at 3^0 for NACA 0015 and given aspect ratio.
A = Effective Aspect Ratio = s^2/P
0.9 = "Oswald" efficiency factor.

$$RNS = \text{Strut Reynolds Number} = \frac{V \cdot ELS}{\nu}$$

$$RNH = \text{Lower Hull Reynolds Number} = \frac{V \cdot ELH}{\nu} .$$

The form factors are input in SWATHGEN, when the panel data file is created. This factor estimates the change in frictional resistance from flat-plate values due to body shape. Very little data is available for these numbers and the defaults are those originally used by Chapman, for a specific SWATH model, (1.17 for the strut, 1.10 for the lower hull). These values may not be appropriate for other models.

The viscous coefficients are found as:

$$CFS = FFS*.075*(\log_{10}RNS-2.0)^{-2}$$

$$CFH = FFH*.075*(\log_{10}RNH-2.0)^{-2}$$

FFS = Strut Form Factor

FFH = Lower Hull Form Factor.

When the total bare hull viscous resistance RF is found, it is non-dimensionalized by the total appended surface area, ST = SS+SH+SAPP. This makes the total frictional resistance coefficient consistent with the wave resistance coefficient:

$$CF = RF/(1/2 \cdot \rho \cdot ST \cdot V^2) .$$

7.3.3 Appendage Resistance

The appendage resistance is estimated as the sum of four components for each appendage:

$$RAPP = RP + RI + RHA + RTI$$

7.3.2 Viscous Resistance

The program considers three components in the viscous resistance; the strut, the lower hull and the correlation allowance.

$$RF = RFS + RFH + RCOR$$

$$RF = \rho/2V^2 * [CFS*SS+CFH*SH+CA*(SS+SH)]$$

where:

RFS = Strut Frictional Resistance
CFS = Strut Frictional Resistance Coefficient
SS = Strut Wetted Surface Area
RF = Bare Hull Frictional Resistance
ρ = Water Density

RFH = Lower Hull Frictional Resistance
CFH = Lower Hull Frictional Resistance Coefficient
SH = Lower Hull Wetted Surface Area
CA = Correlation Allowance
V = Ship Speed

The surface areas are from the SWATHGEN calculation. The division between strut and hull is considered to be the middle of the fairing region. The correlation allowance is a user input. The frictional coefficients are calculated separately for strut and lower hull, with different form factors and characteristic lengths. The coefficients are based on the 1957 I.T.T.C. friction line;

$$Cf = .075\ (\log_{10} R_N - 2.0)^{-2}\ .$$

Where R_N is the Reynold's number. The length for the strut Reynold's number is the strut's average below waterline length. The length for the lower hull is it's nose-to-tail length.

V = ship speed
ν = kinematic viscosity
ELS = strut effective length
ELH = lower hull effective length

and $J(u)$ = complex Kochin function given by:

$$J(u) = 4\pi \int_S \sigma(x,y,z)\, e^{k_0(isx+iuy+wz)}\, dS \tag{7.2}$$

where

$\sigma(x,y,z)$ = source density

S = surface over which the sources are distributed

s,u,w = non-dimensional wave numbers which can be related by

$$s^2 = \frac{1}{2}\left(1 + \sqrt{1+4u^2}\right)$$

and

$$w^2 = u^2 + s^2 \ .$$

Note that all of the information about the vessel's geometry is contained in the Kochin function and that the evaluation of Eq. (7.2) for any complex geometry is the most time consuming aspect of program REPOW. The spectral representation of the free-surface is contained in the product $\beta(u) \cdot J(u)$. Both of these functions are written on the spectral file which is output by REPOW (option 3) and the user has the option of using these functions later as input to OPTVOL for hull optimization.

The wave resistance coefficient is then;

$$CW = RW/(1/2{*}\rho \cdot ST \cdot V^2)$$

where ρ = water density

V = ship speed

ST = total appended wetted surface area.

Once the resistance calculation is complete, the user has several options for saving and examining the data, REPOW options 5 and 6, covered in Sections 7.4 and 7.5. The remainder of this section details the components of the resistance calculation.

7.3.1 Wave Resistance

The development of the wave resistance and optimization calculations used in REPOW and OPTVOL dates back to the late R.B. Chapman's work on the design of the SWATH ship KAIMALINO. Many of his ideas were incorporated into earlier versions of these codes, although there have been many changes since that time. The theory remains unchanged and much of Chapman's notation has been retained to aid those who are familiar with his earlier codes. The development from Chapman's original work was performed by Carl Scragg. The latest versions of his thin ship/slender body codes are the core of REPOW and OPTVOL.

Michell's famous integral for the wave resistance of thin ships was written by Chapman in the following form:

$$R_w = \rho\, k_o^2 \frac{1}{8\pi} \int_{-\infty}^{\infty} \beta(u) \cdot J(u) \cdot J^*(u)\, du \qquad (7.1)$$

where

ρ = density
$k_o = g/V^2$ = characteristic wave number
g = gravitational constant
V = ship velocity

$$\beta(u) = 2(1 + \sqrt{1+4u^2})/\sqrt{1+4u^2}$$

value of CA = .0005 is available. (See Section 7.3.2 for more information.)

3) The number of speeds to be considered up to 30 speeds may be calculated and stored together. The results for these speeds can later be plotted as continuous curves.

4) The speeds in feet per second. The speeds must be entered in ascending order and all must be positive and non-zero.

5) The number of appendages. The appendage suit is assumed to be symmetrical port and starboard. If zero is entered here, the next two inputs are skipped.

6) The appendage dimensions. For each appendage, the program requests a nominal mean chord, thickness and span in feet. Section 7.3.3 shows how these dimensions are used to calculate the appendage resistance.

7) The total appendage wetted surface area for one hull, in ft^2. This is added to bare hull surface area for the total wetted surface.

When these inputs are complete, the calculation begins. During the calculation, the program displays the speed and the source panel which is being calculated. This lets the user know how far the program has come.

The wave resistance calculation requires between 1 and 2 minutes of CPU time for each speed being calculated. For this reason, it is sometimes best to do this operation as a batch run, if a large speed range is required. Instructions for this procedure are given in Appendix D.

7.2 Plots of Source Panels

As a further input verification, the user may plot the panels representing the hull form. The user is asked for a viewpoint (R, PHI, THETA), as in the SWATHGEN 3-D plotting routines, with the same meanings (see Figure 6-1). Note that these plots are done in the REPOW coordinate system (see Appendix A).

The edges of all the quadrilateral and triangular panels are drawn and the endpoints of line sources are indicated with a square marker. Figure C-8 shows an example of such a plot. Places where panels appear to be missing are panels of zero strength.

7.3 Resistance Calculations

The resistance of the SWATH ship is calculated as the sum of three components:

RT = RR + RV + RAPP .

RT = total resistance
RR = wave making resistance, bare hull
RV = viscous resistance, bare hull
RAPP = appendage resistance

When the user chooses option 4 in the REPOW menu, the program requests the following:

1) The mass density of the fluid in slugs/ft^3 and the kinematic viscosity in ft^2/s. The user may enter zero for one or both to take the defaults (Salt Water @ 59°F, ρ = 1.99, V = .1279 x 10^{-4}).

2) The correlation allowance, coefficient, CA. The correlation resistance RCOR is added to the viscous resistance. A default

7.0 REPOW - RESISTANCE AND POWERING MODULE

The program REPOW estimates the resistance and powering characteristics of the SWATH hull forms produced by SWATHGEN. It provides graphical output of its results and comparison of results from two hull forms. It also generates the input required by OPTVOL, for lower hull optimization. Figure 1-3 shows a flow diagram with the major components of REPOW. As in SWATHGEN, the user controls the program flow with a menu of operations, shown below.

```
<<<<<<<<<< REPOW  --  SWATH RESISTANCE AND POWERING

        >>>>>>>>>>MAIN MENU<<<<<<<<<<

   1)  READ IN SWATH PANEL DATA

   2)  THREE-DIMENSIONAL PLOTS OF THE HULL PANELS

   3)  CALCULATE THE FREE SURFACE SPECTRAL FUNCTION
       (FOR OPTVOL INPUT, STRUT DATA ONLY)
   4)  CALCULATE RESISTANCE VERSUS SPEED

   5)  PLOT RESISTANCE VERSUS SPEED

   6)  OUTPUT RESISTANCE VERSUS SPEED

   7)  RETYPE THIS MENU

   8)  STOP


ENTER YOUR MENU CHOICE (7 FOR MENU, 8 TO STOP)
```

7.1 Panel Data Input

As described in Chapter 6, SWATHGEN creates a data file containing source panels and their strengths, for input to REPOW. Before proceeding to calculation of resistance, the user must specify this data file by choosing REPOW option 1. The program will then request the data file name and perform simple checks on the volume and center of buoyancy represented by the source panel distribution, printing the results at the terminal.

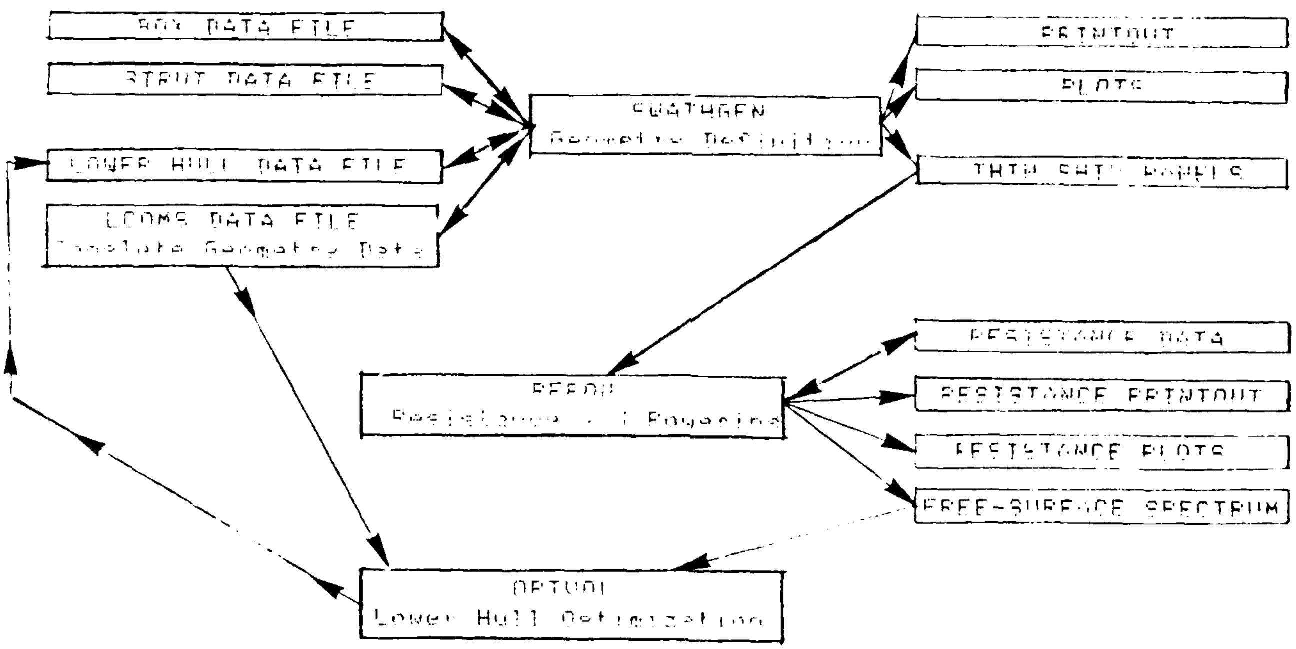


Figure 8-1. SWATHGEN/REPOW/OPTVOL Data Flow

8.1 Optimization Theory

OPTVOL employs the method of Lagrange multipliers, a standard technique for locating maxima and minima in the calculus of variations. An examination of the definitions of the Kochin function, Equation 7.2, shows that if the lower hull can be modeled by N line sources of uniform densities σ_j located at specified positions in space S_j, then

$$J(u) = J(u)_{STRUTS} + 4\pi \sum_{j=1}^{N} \sigma_j \int_{S_j} e^{k_o(isx+iuy+wz)} \, dS \, . \qquad (8.1)$$

We could then express the wave resistance as a function of the unknown source densities σ_j

$$R_w = R_w(\sigma_1, \sigma_2, \sigma_3, \ldots, \sigma_N)$$

subject to whatever further constraints are placed upon the optimization. If we have n constraints which can be expressed as

$$f_k(\sigma_1, \sigma_2, \sigma_3, \ldots, \sigma_N) = 0 \qquad k = 1, 2, \ldots, n$$

then these n equations together with the N differential equations

$$\frac{\partial R_w}{\partial \sigma_j} + \sum_{k=1}^{n} \lambda_k \frac{\partial f_k}{\partial \sigma_j} = 0 \qquad j = 1, 2, \ldots, N \qquad (8.2)$$

Comprise n+N equations in the N unknown source densities σ_j and the n unknown Lagrange multipliers λ_k.

8.2 Constraints on the Optimization

There are three mathematical constraints placed on the optimization, two of which are set by the user

1) Closed body requirement - by requiring that

$$\sum_{j=1}^{N} \sigma_j \cdot \ell_j = 0$$

where

ℓ_j = the length of segment j

we eliminate from the set of all mathematically consistent solution, any body which is not closed. The sources and sinks representing the body must cancel each other out and not contribute fluid to the system or absorb fluid from it.

2) Volume restriction

The user is given the total volume of the original SWATH and asked to input the desired volume with the default of maintaining the original volume. The volume of the lower hull, V_H, is calculated. This gives the following constraint;

$$\nabla_h - 4\pi \sum_{j=1}^{N} \sigma_j \cdot \ell_j \cdot x_j = 0$$

where

x_j = centroid of segment j .

The volumes used are those calculated from the source panel distribution and may differ from those calculated by SWATHGEN by several percent. Also note that if the user chooses to maintain the volume, when the contoured lower hull is faired with the strut in SWATHGEN the volume may change slightly.

3) Center of buoyancy constraint - The code also can restrict the location of the center of buoyancy to a specified position x_c:

$$\nabla_H \cdot x_c - 2\pi \sum_{j=1}^{N} \sigma_j \cdot \ell_j \cdot x_j^2 = 0$$

This requirement is not always desirable and the user has the option of imposing this constraint or allowing the optimization to proceed without regard to the location of the center of buoyancy.

The user is asked to input the center of buoyancy of the entire hull and the center of the lower hull is found from this. As for the volume, the user may maintain the original value as a default.

8.3 Further Restrictions on the Optimization

OPTVOL requires two further inputs from the user, neither of which is strictly a constraint, but both of which affect the optimization.

The user must enter the number of source segments which will define the lower hull (N in Equations 8.1 and 8.2). The endpoints of the lower hull are assumed to be the same as the original, as found in the SWCOMS file. The source segments are then spaced evenly along the centerline. Allowing more source segments provides greater flexibility in hull shape.

Finally, the user is asked to input a "reasonableness" parameter, α, whose effect is implied. Roughly, α measures a trade-off between an actual minimization of wave resistance and an unreasonable hull form.

$\alpha=0$: uncontrolled optimization, which may result in very large fluctuations in the resulting source strengths and thus very large radii and negative radii.

$\alpha \to \infty$: the body becomes an ellipsoid of revolution.

It is recommended that a value α=1.0 be used as a starting point. If the variation of radii is too large, increase α. An example of this is shown in the sample run, Appendix C.

The value of α may also be used to control the trade-off between viscous and wave resistance. Larger α generally implies lower wetted surface, but larger wave resistance.

REFERENCES

Chapman, R.B., "Hydrodynamic Drag of Semisubmerged Ships," Transactions of the ASME, Journal of Basic Engineering, Vol. 94, pp. 879-884, December 1972.

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Hoerner, Sighard F., "Fluid-Dynamic Drag," Practical Information on Aerodynamic Drag and Hydrodynamic Resistance, 1965.

Numata, Edward, "Resistance Test of a Model of the SWATH T-AGOS Initial Baseline Design," Davidson Laboratory Technical Report SIT-DL-81-9-2216, July 1981.

von Kerczek, Christian, Carl A. Scragg and Gene A. Morgan, "Some Hydrodynamic Aspects of SWATH Ships," Science Applications, Inc. Report 463-81-145-LJ, April 1981.

Appendix A   COORDINATE SYSTEMS

Global Coordinate System

The global coordinate system used in the SWATHGEN computer system is defined as follows:

Origin:	x = 0	at the leading edge-waterplane intersection
	y = 0	at the centerplane of the ship
	z = 0	at the waterplane
Orientation	x	is the flow direction positive aft
	y	is positive to starboard
	z	is vertical positive upward

Figure A-1 shows the axes of this system plotted with a sample hull. The output from SWGEN is given in this coordinate system unless otherwise stated.

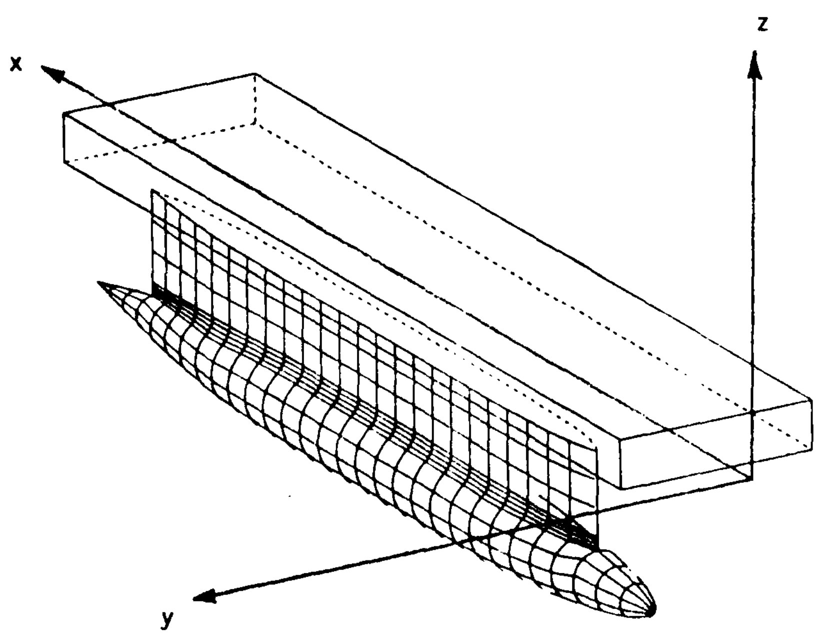

Figure A-1. Global coordinate system.

Strut Local Coordinate System

The axes for this system are parallel to those of the global system. The origin is translated in the y direction so that y=0 at the leading edge-waterplane intersection point. The strut local coordinate system is used primarily for the lower hull positioning. Figure A-2 shows strut local coordinate axes plotted with a sample hull.

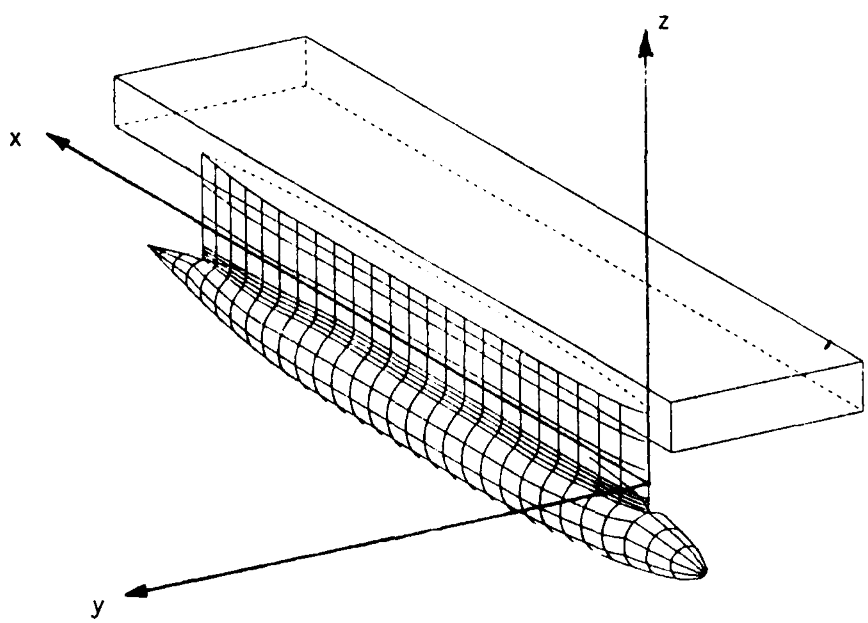

Figure A-2. Strut local coordinate system.

Lower Hull Local Coordinate System

The lower hull local coordinate system is defined as follows:

Origin at the lower hull nose

x is along the lower hull centerline, positive aft

y is horizontal positive starboard

z is positive upward but is canted from a vertical by the nose-up angle of the lower hull.

This coordinate system is used to define the lower hull surface (axisymmetric about x) and in the construction of the fairing curves. Figure A-3 shows the lower hull local coordinate axes in relation to a sample hull.

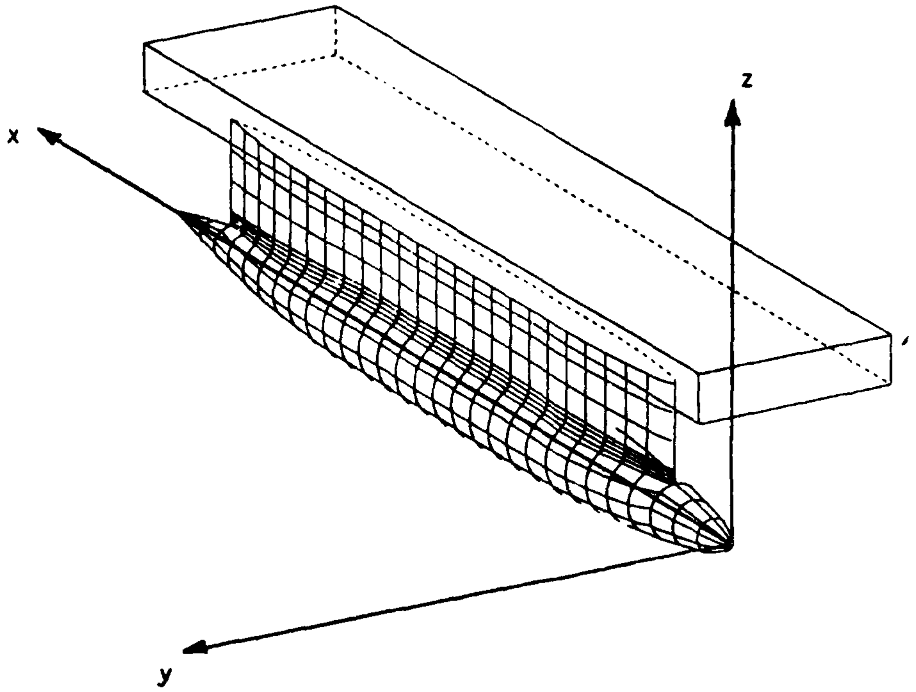

Figure A-3. Lower hull local coordinate system.

REPOW/OPTVOL Coordinate System

The data file created by SWATHGEN as input to REPOW contains source panels in the following coordinate system. The user, however, is never asked for input or given output in this coordinate system.

Origin:	x = 0	at the leading edge-waterplane intersection
	y = 0	at the centerplane of the ship
	z = 0	at the waterplane
Orientation	x	is the flow direction positive fwd
	y	is positive to port
	z	is vertical positive upward

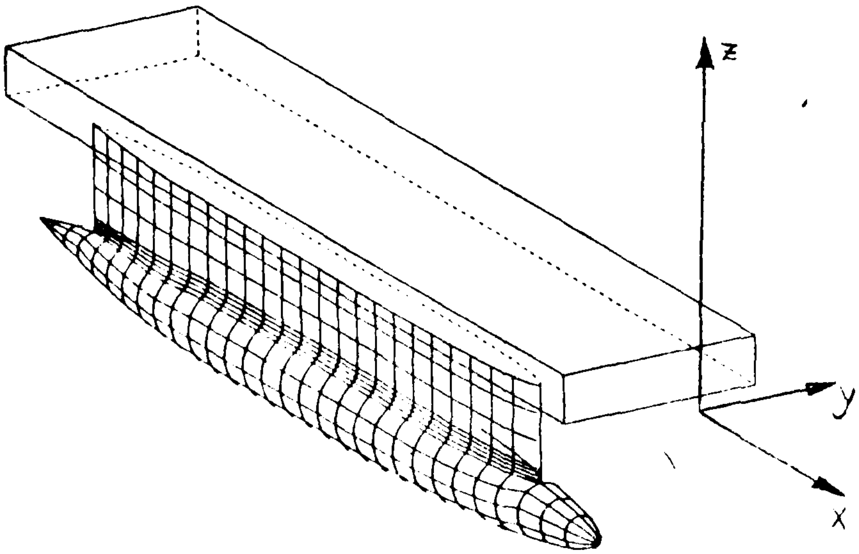

Figure A-4. REPOW/OPTVOL Coordinate System.

Appendix B SWCOMS DATA FILE DESCRIPTION

This binary file contains the data stored in the COMMON areas of the SWATHGEN source code. SWCOMS contains a complete description of the hull surface. It also contains the input data and fairing parameters used to create the hull surface. The FORTRAN write statements for this file are shown below. All variable names follow the standard FORTRAN convention for integers and floating point numbers (integers: I-N, real: A-H, O-Z) except for NAME which is a character variable of length 80.

```
      OPEN(UNIT=30,FILE=FIL,STATUS='NEW',FORM='UNFORMATTED',ERR=999)
      WRITE(30) NAME
      WRITE(30) ICRV,HL1,HL2,HL3,HRMAX,RFIL,NFF,NFA
      WRITE(30) NHI,((HXI(I),HRI(I)),I=1,NHI)
      WRITE(30) HNU,HTO,HH,HD,HN(1),HN(2),HN(3),
     .                             CEL,XEF,XEA
      WRITE(30) NH,((HX(I),HR(I),HR2(I),HR2P(I)),
     .                             I=1,NH)
      WRITE(30) SL1,SL2,SL3,SLT,SOV,SF3,SAT,SAF,SAA,
     .                      SAC,STO,SSS
      WRITE(30) BDD,BDC,BDF,BDA,BDW
C   GRID VALUES
      WRITE(30) (IDIV(I),I=1,5),((JTAN(I,J),J=1,2),
     .                             I=1,6),NGI
      WRITE(30) (A(I),I=1,AMAXO(NGI,IDIV(5)))
      WRITE(30) (B(I),I=1,JTAN(6,2))
      DO 1200 I=1,AMAXO(NGI,IDIV(5))
       JL=1
       JH=JTAN(6,2)
       IF(I.LE.IDIV(1).OR.I.GT.IDIV(5)) THEN
        JL=JTAN(3,2)
        JH=JTAN(4,2)
       END IF
       DO 1210 J=JL,JH
        WRITE(30) (G(I,J,K),K=1,12)
1210   CONTINUE
1200  CONTINUE
C   FAIRING PARAMETERS
      WRITE(30) IFTYP,ILETE,FFY(1),FFY(2),ROF,RIF,
     .                   ((XMID(I,J),J=1,2),I=1,2),ZCLR
      WRITE(30) ((RO(I),RI(I),FZO(I),FD(I),((IFT(I,J),
     .          IFS(I,J),AO(I,J),DR(I,J)),J=1,2)),I=IDIV(1)+1,IDIV(4))
      DRE(1)=DR(IDIV(1)+1,2)
      DRE(2)=DR(IDIV(4),2)
C   HULL PROPERTIES
      WRITE(30) HVOL,SVOL,FVOL,AREAS,AREAH,
     . ((DRAFT(I),BEAM(I),CB(I),(FCLR(I,J),J=1,2)),I=1,3)
      WRITE(30) AWP,XLCF,YMYC,XMYO,XIX,XIYC,XIYO
      CLOSE(UNIT=30)
```

HULL NAME

NAME An 80 character variable name for the hull

LOWER HULL INPUT DATA

ICRV Lower Hull Spline Method Number

HL1 Elliptic Nose Length (ICRV=4)

HL2 Parallel Mid-Section Length (ICRV=4)

HL3 Parabolic Tail Length (ICRV=4)

HRMAX Mid-Section Vertical Radius (ICRV=4)

RFIL Filletting Radius (ICRV=3)

NFF First Input Point for Filletting (ICRV=3)

NFA Last Input Point for Filletting (ICRV=3)

NHI Number of Input Vertical Radii (ICRV=1,2,3)

(HX(I),HR(I),I=1,NH) The values of x and r along the hull centerline

HNU Lower Hull nose-up Angle (radians)

HTO Lower Hull Toe-out Angle (radians)

HH Lower Hull Centerline Depth at Midship (see Figure 2-10)

HD Distance from Lower Hull Centerline to Strut Outboard Panel at Midship (see Figure 2-10)

HN(1)=HN(3) (x,y,z) coordinates of the lower hull nose given in the strut coordinate system

CEL Elliptic ratio, horizontal radius/vertical radius

XEF X-coordinate in the lower hull system of the start of the transition from elliptic to circular sections

XEA X-coordinate of the end of the transition region - all circular sections aft of this

NH The number of spline knots for the lower hull radius distribution function

(HX(I),HR(I)HR2(I),HR2P(I)) I=1,NH The values of X, R, R^2 and dR^2/dx respectively at the NH knots on the lower hull centerline. HX is given in the lower hull coordinate system with NOSE=HX(1)=0; TAIL=HX(NH)=lower hull length

STRUT INPUT DATA

SL1	Waterplane elliptic fore-section length
SL2	Overhang strut waterplane parallel mid-section length
SL3	Overhang strut waterplane parabolic tail-section length
SLT	Waterplane mid-section thickness
SOV	Overhang
SF3	Fairing strut parabolic tail-section length
SAT	Transverse taper angle (radians)
SAF	Leading edge inclination angle (radians)
SAA	Trailing edge inclination angle (radians)
SAC	Inward cant angle (radians)
STO	Toe-out angle (radians)
SSS	Strut separation at leading edge-waterplane

BOX DATA

BDD	Depth
BDC	Clearance
BDF	Forward overhang
BDA	Aft overhang
BDW	Total width

SURFACE GRID DATA

IDIV(I),I=1,5 The I index for the grid lines corresponding to the 1) leading edge, 2) strut mid-section forward border, 3) strut mid-section aft border, 4) trailing edge, and 5) overhang trailing edge. Note: The leading and trailing edges have double valued I indices. IDIV contains the lower of the two values.

((JTAN(I,J),J=1,2),I=1,6) Array giving the J indices bordering each of the six girth regions (Figure 4-3). J=1 gives the index for the lower boundary, J=2 gives the J index for the upper boundary.

NGI The I index at the lower hull tail (Figure 4-2b)

A(I),I=1,AMAXO(NGI,IDIV(5)) The α parameter values for each of the I indices on the grid.

B(J),J=1JTAN(6,2) The β parameter values for each of the JTAN(6,2) J indices on the grid.

(G(I,J,K),K=1,12) This array contains surface values R, R_α, R_β and $R_{\alpha\beta}$ for each of the I,J knots on the grid as follows:

K = 1,3	x, y and z coordinates
K = 4,6	x_α, y_α and z_α derivatives
K = 7,9	x_β, y_β and z_β derivatives
K = 10,12	$x_{\alpha\beta}$, $y_{\alpha\beta}$ and $z_{\alpha\beta}$ derivatives

FAIRING PARAMETERS

IFTYP Outboard fairing method

ILETE LE/TE fairing method

ROF Outboard mid-section fairing radius (IFTYP=1 or 3 only)

RIF Inboard mid-section fairing radius

FEY(1),FEY(2) The y offsets from the lower hull centerline of the fairing-lower hull intersection points on the leading and trailing edges respectively.

((XMID(I,J),J=1,2),I=1,2) The fractional lengths used to set the mid-section fairing region boundaries. Inboard (I-1), outboard (I=2), fore (J=1), aft (J=2)

ZCLR The input value for the maximum allowable fairing level.

((RO(I),RI(I),FZO(I),FD(I),((IFT(I,J),IFS(I,J),AO(I,J), DR(I,J)),J-1,2), 2)),I=IDIV(1)+1,IDIV(4))
These are the parameters used in the nine fairing construction routines, F1 - F9. These values are stored for each of the grid I's between the leading edge (IDIV(1)+I) and the trailing edge (I=IDIV(4)).

RIF Inboard fairing radius

ROF Outboard fairing radius

FZO ZO (routine F1)

FD Δf (routine F1)

AO A_0 (routines F1, F8)

DR DR (routines F1, F7, F8, F9)

AD-A154 859 SWATHGEN COMPUTER-AIDED DESIGN SYSTEM USER'S MANUAL(U) 2/2
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UNCLASSIFIED DTCG23-83-20057 F/G 9/2 NL

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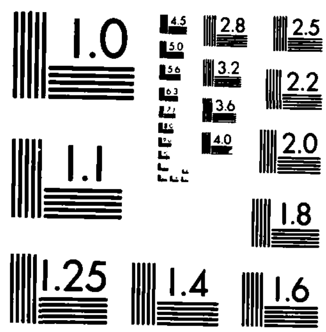

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

IFT(I,J) Records the fairing construction routine (1-9) used at each fairing section I; inboard (J=1) and outboard (J=2)

IFS(I,J)=1,2 or 3 based on whether the fairing curve I lies in the forward transition fairing region, mid-section fairing region or aft transition fairing region. J=1 for inboard and J=2 for outboard.

HULL PROPERTIES DATA (all for a single hull)

HVOL	Below waterline hull displaced volume (single hull)
SVOL	The strut displaced volume (SVOL = HVOL - PVOL)
PVOL	The lower hull displaced volume calculated for a body of revolution
AREAS	The strut wetted surface area
AREAH	The lower hull wetted surface area

DRAFT(I),I=1,3 The x,y,z position of maximum draft on the hull (global coordinate system)

BEAM(I),I=1,3 The x,y,z position of the maximum beam of the lower hull (global coordinate system)

CB(I),I=1,3 The x,y,z coordinates of the hull center of buoyancy (global coordinate system)

((FCLR(I,J),J=1,2),I=1,3) The x,y,z position of the minimum fairing depth below the waterline inboard (J=1) and outboard (J=2) (global coordinate system)

AWP	The waterplane area
XLCF	The longitudinal center of flotation in the global coordinate system
XMYC	The transverse first moment of waterplane area about the y-centroid
XMYO	The transverse first moment of waterplane area about y=0, the global x-axis
XIX	The longitudinal second moment of waterplane area about the x-centroid
XIYC	The transverse second moment of waterplane area about the y-centroid
XIYO	The transverse second moment of waterplane area about y=0, the global x-axis

Appendix C SAMPLE RUNS

This sample run shows the creation of a SWATH hull form using terminal input. The initial lower hull form consists of an elliptic nose, parallel midsection and parabolic tail. After the hull is developed, the SWCOMS file is saved, the hull data is printed out, and finally, a panel data file is created for input to REPOW.

Using REPOW, input is created for OPTVOL. Then OPTVOL is used to create a new lower hull data file for SWATHGEN. This is combined with the original SWCOMS file to create a new hull. Finally the resistance of each hull is calculated and compared.

```
$   SWATHGEN

 ENTER TERMINAL TYPE : 1 FOR TEKTRONIX, 2 FOR CIT-101:
2

*************
SWATHGEN MENU
*************
     1) SWIN (,SWMOD,SWGRID,SWPROP) - generate hull form
     2) SWMOD,SWGRID,SWPROP - modify hull form
     3) SWPRNT - descriptive printout
     4) SWPLOT - plot
     5) SWOUT - create SWCOMS output or DUPLICATE INPUT data files
     6) NAME OR RENAME HULL
     7) PANTHN - panelization for REPON/OPTVOL input
 ENTER YOUR CHOICE 1-6, "0" TO STOP


1


=========
SWIN MENU
=========
  1) ENTER STRUT DATA
  2) ENTER BOX DATA
  3) ENTER LOWER HULL DATA
  4) 1,2,AND 3 IN SEQUENCE
  5) READ IN SWCOMS FILE FOR EXISTING HULL
  6) READ ONLY STRUT DATA FROM AN SWCOMS FILE
  7) READ ONLY BOX DATA FROM AN SWCOMS FILE
  8) READ ONLY LOWER HULL DATA FROM AN SWCOMS FILE
ENTER CHOICE 1-8, RETURN TO EXIT SWIN
4

 ENTER STRUT INPUT FILE NAME (HIT RETURN FOR TERMINAL INPUT).



...STRUT DESCRIPTION...

-STRUT WATERPLANE PARAMETERS BEFORE CANTING-
ENTER SL1,SL2,SL3,SLT WHERE:
  SL1 = ELLIPTIC FOREBODY LENGTH
  SL2 = PARALLEL MIDBODY LENGTH
  SL3 = PARABOLIC TAIL LENGTH
  SLT   MIDBODY WIDTH
20   30   40   10
```

```
- STRUT OVERHANG PARAMETERS -
ENTER SOV,SF3 WHERE:
  SOV = STRUT OVERHANG PAST THE FAIRING TRAILING EDGE
  SF3 = LENGTH OF STRUT PARABOLIC TRAILING SECTION FOR FAIRING
        SET SOV=0 FOR NO OVERHANG
10    25


-STRUT VERTICAL PARAMETERS BEFORE CANTING-
ENTER SAT,SAF,SAA WHERE:
  SAT = TRANSVERSE TAPER HALF ANGLE (DEG) OF FLAT SIDES
  SAF = INCLINATION ANGLE (DEG) OF LEADING EDGE (+ AFT, 0.0 FOR VERTICAL)
  SAA = INCLINATION ANGLE (DEG) OF TRAILING EDGE (+ AFT, 0.0 FOR VERTICAL)

0 -10  10


-STRUT ORIENTATION-
ENTER SAC,STO,SSS WHERE:
  SAC = STRUT CANT ANGLE (DEG)
  STO = STRUT TOE OUT ANGLE (DEG)
  SSS = STRUT SEPARATION AT LEADING EDGE ON WATERLINE

12 0 55

 CREATE A FILE DUPLICATE OF THIS INPUT SESSION FOR LATER USE.
 ENTER FILE NAME OR HIT RETURN FOR DEFAULT - 'SDUP.DAT'.


 ENTER BOX INPUT FILE NAME (HIT RETURN FOR TERMINAL INPUT).


... BOX DESCRIPTION...

ENTER BDD,BDC,BDF,BDA,BDW WHERE:
  BDD = BOX DEPTH
  BDC = CLEARANCE ABOVE WATERLINE
  BDF   FORWARD OVERHANG(PAST STRUT)
  BDA= AFT OVERHANG(PAST STRUT)
  BDW = BOX WIDTH

8   10    3     19   63

 CREATE A FILE DUPLICATE OF THIS INPUT SESSION FOR LATER USE.
 ENTER FILE NAME OR HIT RETURN FOR DEFAULT = 'BDUP.DAT'.


 ENTER LOWER HULL INPUT FILE NAME (RETURN FOR TERMINAL INPUT)
```

```
 CHOOSE A METHOD FOR DEFINING THE LOWER HULL:

                CURVE FIT TO (X,R) OFFSETS
  1)  CURVE TANGENT TO MIDPOINTS OF CONNECTING SEGMENTS
  2)  CURVE FIT THROUGH POINTS
  3)  FILLETTED CONES AND CYLINDERS WITH SMOOTHED NOSE AND TAIL

                PARAMETRIC DESCRIPTION
  4)  ELLIPTIC-PARALLEL-PARABOLIC HULL

 ENTER 1,2,3, OR 4
4


PARAMETRIC LOWER HULL DESCRIPTION
-----------------------------
         HL1 = ELLIPTIC FOREBODY LENGTH
         HL2 = PARALLEL MID-BODY LENGTH
         HL3 = PARABOLIC TAIL SECTION LENGTH
         RMAX = MID-BODY RADIUS
 ENTER HL1,HL2,HL3,RMAX
30 40 30 7


 ENTER  CEL,XEF,XEA  WHERE:

         CEL   RATIO OF HORIZONTAL AXIS LENGTH TO VERTICAL AXIS LENGTH
         XEF = DISTANCE FROM NOSE ALONG HULL CENTERLINE
               TO BEGIN BLENDING TO CIRCULAR SECTION
         XEA = DISTANCE FROM NOSE ALONG HULL CENTERLINE
               WHERE SECIONS BECOME CIRCULAR
               NOTE: MUST HAVE XEA>XEF
                     SET CEL 1. FOR ALL CIRCULAR SECTIONS
                     SET XEF>HULL LENGTH FOR ALL ELLIPTIC SECTIONS
                     HULL LENGTH =      100.000000
1.3 75 90


 ENTER NOSE-UP AND TOE-OUT ANGLES (DEG).
1 0

 LOCATE HULL RELATIVE TO STRUT LE (STRUT COORDS: X +AFT, Y +STBD, Z +UP)

 ENTER : (XN,D,H)    TO SET POSITION AT MIDSHIP (H POSITIVE)
      OR (XN,YN,ZN)   TO SET NOSE POSITION

    WHERE: (XN,YN,ZN) = THE COORDINATES OF THE LOWER HULL NOSE
                      H = THE LOWER HULL CENTERLINE DEPTH AT MIDSHIP
                           TO THE STRUT CENTERPLANE
                      D = THE DISTANCE AT MIDSHIP FROM THE LOWER HULL CENTERLINE
-12  3  -12

 CREATE A FILE DUPLICATE OF THIS INPUT SESSION FOR LATER USE.
 ENTER FILE NAME OR HIT RETURN FOR DEFAULT = 'LDUP.DAT'.
```

```
=========
SWIN MENU
=========
ENTER CHOICE 1-8, '9' TO PRINT SWIN MENU, RETURN TO EXIT SWIN
==========
SWMOD MENU
==========
    NOTE:  THE VALUE '0' WILL LEAVE ANY VALUE UNCHANGED IN THE ROUTINES BELOW
           OR INVOKE A DEFAULT VALUE IF THE VARIABLE HAS NOT BEEN PREVIOUSLY SET
           (ENTER 1.E-6 IF A ZERO VALUE IS REQUIRED.)

        1) MODIFY LOWER HULL ONLY
        2) MODIFY STRUT ONLY
        3) MODIFY BOX ONLY
        4) SET OR MODIFY FAIRING PARAMETERS
        5) CHANGE DESIGN WATERLINE
        6) RESCALE ENTIRE HULL CONFIGURATION
        7) PLOT UNFAIRED HULL CONFIGURATION
        8) RETURN TO SWATHGEN MENU

  ENTER SWMOD CHOICE 1-8, OR HIT RETURN TO RUN SWGRID


FAIRING PARAMETERS
------------------


 SELECT ONE OF THE THREE OUTBOARD FAIRING METHODS
        METHOD 1    *VERTICAL OR SLANTED STRUTS ALIGNED
                      WITH THE LOWER HULL

        METHOD 2    *SLANTED STRUTS ONLY
                    *VARIABLE OUTBOARD MID-SECTION FAIRING RADIUS

        METHOD 3    *SLANTED STRUTS ONLY
                    *CONSTANT OUTBOARD MID-SECTION FAIRING RADIUS
                    *THE STRUT LINE BOUNDARIES OF THE OUTBOARD MID-SECTION
                      FAIRING REGION MUST NOT INTERSECT THE LOWER HULL SURFACE
 ENTER 1,2,OR 3
2

 SELECT OF THE THREE LEADING EDGE/TRAILING EDGE FAIRING METHODS
        1.   GIVEN RADIAL DISTANCE DR FROM LOWER HULL, FAIR TO LOWER HULL NORMAL
        2.   GIVEN DR FAIR TO LOWER HULL AT GIVEN Y LOWER HULL COORDINATE
        3.   GIVEN DR FAIR TO VERTICAL AT Z=0(LOWER HULL CENTERLINE)
 ENTER 1,2,OR 3

 3

 ENTER DR(LE),DR(TE) = RADIAL DISTANCES FROM LOWER HULL AT WHICH
                       TO START FAIRING OF LEADING AND TRAILING EDGES
                NOTE: DR(TE) ALSO SETS THE OVERHANG HEIGHT IF SOV>0.


4. 3.5
```

```
 ENTER RI = INBOARD MID-SECTION FAIRING RADIUS
12.


 ENTER  XOF,XOA,XIF,XIA

  * THESE VALUES SET THE OUTBOARD; FORE AND AFT; AND INBOARD; FORE AND AFT
     BOUNDARIES, RESPECTIVELY FOR THE MID-SECTION FAIRING REGIONS OF THE HULL.
  * ENTER THE VALUES AS FRACTIONS OF STRUT LENGTH FROM THE
     LEADING EDGE TO THE FORWARD BOUNDARIES AND FROM THE TRAILING EDGE
     TO THE AFT BOUNDARIES
  * ALL VALUES ARE FRACTIONS BETWEEN 0. AND 1.
  * THE DEFAULT BOUNDARIES ARE THE BORDERS OF THE STRUT
     PARALLEL MID-SECTION (SET X<0. FOR DEFAULT BOUNDARIES)

0 0 0 0


 ENTER ZCLR = MAXIMUM FAIRING HEIGHT (Z=0 IS WATERPLANE)
2.


==========
SWMOD MENU
==========

 ENTER SWMOD CHOICE 1-8, OR 9 FOR SWMOD MENU, OR HIT RETURN TO RUN SWGRID


================
SWGRID EXECUTION
================
 GRID GENERATION COMPLETE


================
SWPROP EXECUTION
================
 HULL PROPERTIES CALCULATED

*************
SWATHGEN MENU
*************

 ENTER YOUR CHOICE 1-7,  "8" TO PRINT MENU,  "0" TO STOP
6


 ENTER NEW HULL NAME (RETURN FOR NO CHANGE):
SWATHGEN USER'S MANUAL EXAMPLE #1
```

```
*************
SWATHGEN MENU
*************

 ENTER YOUR CHOICE 1-7,  '8' TO PRINT MENU,  '0' TO STOP
5


 =========
SWOUT MENU
 =========
  1) WRITE DUPLICATE FILE OF STRUT DATA
  2) WRITE DUPLICATE FILE OF BOX DATA
  3) WRITE DUPLICATE FILE OF LOWER HULL DATA
  4) 1,2,AND 3 IN SEQUENCE
  5) WRITE SWCOMS DATA FILE FOR EXISTING HULL

ENTER CHOICE 1-5, '6' TO PRINT SWOUT MENU, RETURN TO EXIT SWOUT
5


 ENTER THE NAME OF THE SWCOMS DATA FILE, DEFAULT 'SWCOMS.DAT'.
EXMPC1


*************
SWATHGEN MENU
*************

 ENTER YOUR CHOICE 1-7,  '8' TO PRINT MENU,  '0' TO STOP
3
 ==== ==========
SWPRNT EXECUTION
 ===============

 ENTER FILE NAME FOR DESCRIPTIVE PRINTOUT
  (ENTER 'TTY' FOR TERMINAL OUTPUT;  HIT RETURN FOR NO OUTPUT)
TTY



 -----------------------------------------------------------------

 SWATHGEN USER'S MANUAL EXAMPLE #1
 -----------------------------------------------------------------

    NOTE: ALL POSITIONS ARE GIVEN IN THE GLOBAL COORDINATE SYSTEM EXCEPT
          THE LOWER HULL RADII GIVEN ALONG THE CENTERLINE.
```

BOX DESCRIPTION

BOX LENGTH		=	102.376583
BOX DEPTH	BDD	=	9.000000
BOX CLEARANCE	BDC		10.000000
FORWARD OVERHANG	BOF	=	3.000000
AFT OVERHANG	BDA		19.000000
BOX WIDTH	BDW	=	63.000000

STRUT DESCRIPTION

LENGTH BETWEEN PERPENDICULARS		=	90.000000
ELLIPTIC FOREBODY LENGTH	SL1	=	20.000000
PARALLEL MIDBODY LENGTH (WATERPLANE)	SL2		30.000000
PARABOLIC TAIL LENGTH	SL3	=	40.000000
MIDBODY THICKNESS	SLT		10.000000
OVERHANG LENGTH FROM FAIRING TRAILING	SOV	=	15.000000
PARABOLIC TAIL LENGTH FOR FAIRING	SF3		35.000000
OVERHANG HEIGHT	Z	=	-5.170279
TRANSVERSE TAPER HALF ANGLE	SAT	=	5.0000 (DEG)
LEADING EDGE INCLINATION ANGLE	SOF	=	-10.0000 (DEG)
TRAILING EDGE INCLINATION ANGLE	SAA		10.0000 (DEG)
CANT ANGLE	SOC	=	12.0000 (DEG)
TOE-OUT ANGLE	STO		0.0000 (DEG)
LEADING EDGE - WATERPLANE SEPERATION	SSS	=	25.000000

LOWER HULL DESCRIPTION

CENTERLINE LENGTH		=	100.000000
TOE-OUT ANGLE		=	0.0000 (DEG)
NOSE-UP ANGLE		=	1.0000 (DEG)
NOSE AT:	X	=	-12.000005
	Y	=	30.499998
	Z	=	-11.999993
TAIL AT:	X	=	87.984764
	Y	=	30.500000
	Z	=	-13.745237
MIDSHIP POSITION: CENTERLINE DEPTH,	H	=	12.991939
CENTERLINE-STRUT DISTANCE,	D	=	0.232443
MAXIMUM DRAFT AT:	X	=	38.929254
	Y	=	30.500002
	Z	=	-20.230784
MAXIMUM BEAM AT:	X	=	48.134006
	Y	=	39.595908
	Z	=	-13.044748

ELLIPTIC CHORD RATIO	CEL	=	1.300000
START OF BLENDING TO CIRCULAR SECTIONS	XEF		75.000000
START OF CIRCULAR SECTIONS	XEA	=	90.000000

NOTE: XEF,XEA ARE IN LOWER HULL COORDINATES

NITIAL LOWER HULL DESCRIPTION

LOWER HULL IS DESCRIBED PARAMETRICALLY	ICRV	=	4
ELLIPTIC NOSE SECTION LENGTH	HL1	=	30.000000
PARALLEL MID-SECTION LENGTH	HL2		40.000000
PARABOLIC TAIL SECTION LENGTH	HL3	=	30.000000
MID-SECTION RADIUS	RMAX		7.000000

NAL RADII DISTRIBUTION

X	R	dR/dX	CEL	AREA
0.000000	0.000000	**********	1.300000	0.000000
3.333333	3.206860	0.452733	1.300000	42.000393
6.666667	4.399776	0.288735	1.300000	79.059532
10.000000	5.217492	0.208700	1.300000	111.177483
13.333333	5.820356	0.155902	1.300000	138.374172
16.666666	6.270645	0.115766	1.300000	160.589691
20.000000	6.599663	0.082496	1.300000	177.883957
23.333334	6.824973	0.053182	1.300000	190.237030
26.666666	6.956656	0.026087	1.300000	197.648834
30.000000	7.000000	0.000000	1.300000	200.119461
33.333332	7.000000	0.000000	1.300000	200.119461
36.666668	7.000000	0.000000	1.300000	200.119461
40.000000	7.000000	0.000000	1.300000	200.119461
43.333332	7.000000	0.000000	1.300000	200.119461
46.666668	7.000000	0.000000	1.300000	200.119461
50.000000	7.000000	0.000000	1.300000	200.119461
53.333336	7.000000	0.000000	1.300000	200.119461
56.666668	7.000000	0.000000	1.300000	200.119461
60.000000	7.000000	0.000000	1.300000	200.119461
63.333332	7.000000	0.000000	1.300000	200.119461
66.666672	7.000000	0.000000	1.300000	200.119461
70.000000	7.000000	0.000000	1.300000	200.119461
73.333336	6.913580	-0.051852	1.300000	195.208755
76.666664	6.654321	-0.103704	1.290954	179.584198
80.000000	6.222222	-0.155556	1.225000	148.996811
83.333336	5.617283	-0.207407	1.123953	111.416771
86.666664	4.839507	-0.259259	1.035093	76.160835
90.000000	3.888889	-0.311111	1.000000	47.511745
93.333336	2.765431	-0.362963	1.000000	24.025671
96.666664	1.469137	-0.414815	1.000000	6.780700
100.000000	0.000000	-0.466667	1.000000	0.000000

```
HYDROSTATIC QUANTITIES   (ALL QUANTITIES FOR SINGLE HULL)
----------------------

    TOTAL DISPLACED VOLUME                                   =   0.191941E+05
    LOWER HULL DISPLACED VOLUME                              =   0.149730E+05
    STRUT DISPLACED VOLUME                                   =   0.422108E+04
    LOWER HULL WETTED SURFACE AREA                           =   0.388172E+04
    STRUT WETTED SURFACE AREA                                =   0.102560E+04

    CENTER OF BOUYANCY AT:                              X    =   0.361099E+02
                                                        Y    =   0.299475E+02
                                                        Z    =  -0.107209E+02

    WATERPLANE AREA                                          =   0.740465E+03
    LONGITUDINAL CENTER OF FLOTATION, AFT OF FP              =      40.937904
    LONGITUDINAL SECOND MOMENT OF WATERPLANE, ABOUT LCF      =   0.361737E+06
    TRANSVERSE SECOND MOMENT OF WATERPLANE, ABOUT X-AXIS         0.561774E+05



STRUT-LOWER HULL FAIRING PARAMETERS
-----------------------------------

    OUTBOARD FAIRING METHOD                                  = 2
    LE/TE FAIRING METHOD                                     = 3

    DELTA R (LE)                                             =       4.000000
    DELTA R (TE)                                             =       3.500000

    LE Y-OFFSET FROM LOWER HULL CENTERLINE                   =       0.000000
    TE Y-OFFSET FROM LOWER HULL CENTERLINE                   =       0.000000

    MAXIMUM INBOARD FAIRING HEIGHT AT:                  X    =      20.078037
                                                        Y    =      22.992735
                                                        Z    =      -2.293482

    MAXIMUM OUTBOARD FAIRING HEIGHT AT:                 X    =       5.136934
                                                        Y    =      31.098434
                                                        Z    =      -2.396048

    MID-SECTION BOUNDARY POSITIONS:                     XOF  =       0.000000
                                                        XOA  =       0.000000
                                                        XIF  =       0.000000
                                                        XIA  =       0.000000
```

FAIRING SECTIONS

	INBOARD			OUTBOARD		
SECTION	SECTION TYPE	CONSTRUCTION ROUTINE	FAIRING RADIUS	SECTION TYPE	CONSTRUCTION ROUTINE	FAIRING RADIUS
6	LE/TE	F1	58.33793	LE/TE	F1	58.33793
7	TRANS	F8	38.22502	TRANS	F1	67.97741
8	TRANS	F8	16.11179	TRANS	F1	86.08751
9	TRANS	F8	12.65838	TRANS	F1	88.06219
10	TRANS	F8	11.52117	TRANS	F1	89.22763
11	TRANS	F8	11.30656	TRANS	F1	91.86732
12	TRANS	F8	11.57011	TRANS	F1	96.09661
13	MID	F6	12.00000	MID	F1	103.98673
14	MID	F6	12.00000	MID	F1	103.45321
15	MID	F6	12.00000	MID	F1	102.81792
16	MID	F6	12.00000	MID	F1	102.28093
17	MID	F6	12.00000	MID	F1	101.74199
18	MID	F6	12.00000	MID	F1	101.20133
19	MID	F6	12.00000	MID	F1	100.65992
20	MID	F6	12.00000	MID	F1	100.11464
21	MID	F6	12.00000	MID	F1	99.56957
22	MID	F6	12.00000	MID	F1	99.49270
23	TRANS	F8	11.38683	TRANS	F1	93.26911
24	TRANS	F8	10.72121	TRANS	F1	86.81039
25	TRANS	F8	10.34844	TRANS	F1	80.98249
26	TRANS	F8	10.49685	TRANS	F1	75.43296
27	TRANS	F8	11.37015	TRANS	F1	69.37888
28	TRANS	F8	13.42610	TRANS	F1	60.27164
29	TRANS	F8	20.44684	TRANS	F1	49.44280
30	LE/TE	F1	12.66790	LE/TE	F1	12.66790

SURFACE GRID DATA

TOTAL NUMBER OF HULL PANELS = 754
NUMBER OF PANELS LENGTHWISE 35
NUMBER OF PANELS GIRTHWISE = 26

I INDEXES THE ALPHA LENGTHWISE SURFACE PARAMETER
J INDEXES THE BETA GIRTHWISE SURFACE PARAMETER

THE I's CORRESPOND TO LONGITUDINAL DIVISIONS OF THE HULL SURFACE AS FOLLOWS:

NOSE	I = 1
STRUT LEADING EDGE	I = 5- 6
STRUT FAIRING TRAILING EDGE	I = 30-31
TAIL	I = 36
STRUT OVERHANG TRAILING EDGE	I = 36

```
$
$ SUBMIT/NOTIFY/NOLOG/NOPRINT/QUE=SLOW  EXMP1
  Job 1104 entered on queue SLOW
$
$ SUBMIT/NOTIFY/NOLOG/NOPRINT/QUE=SLOW  EXMP2
  Job 1105 entered on queue SLOW
$
```

The following four pages show the resistance data print-out, and the remainder of this appendix is the plots created during this sample run, Figures C-1 to C-14 .

Now the resistance properties of the two hulls can be calculated and compared using REPOW. Since a full range of speeds is desired, it is best to do the resistance calculation as a batch job. The command files for these runs are shown below (see appendix D for more information). When the calculations are complete, the numerical data can be examined, and comparative plots made of resistance, EHP and resistance coefficients, as shown below.

```
$
$ TY EXMP1.COM
$CODE
$REPOW
2
1
EXMPP1
4
0 0
0
15
15 16 17 18 20 22 24 26 28 30 33 36 40 44 49
0
6
EXMPT1
EXMPR1
8
$EXIT

$
$ TY EXMP2.COM
$CODE
$REPOW
2
1
EXMPP2
4
0 0
0
15
15 16 17 18 20 22 24 26 28 30 33 36 40 44 49
0
6
EXMPT2
EXMPR2
8
$EXIT
```

```
--------------------------------------------------------------------------------

SER'S MANUAL EXAMPLE - 1ST OPTIMIZATION
--------------------------------------------------------------------------------

    NOTE: ALL POSITIONS ARE GIVEN IN THE GLOBAL COORDINATE SYSTEM EXCEPT
          THE LOWER HULL RADII GIVEN ALONG THE CENTERLINE.

OX DESCRIPTION
-------------
       •
       •
       •

YDROSTATIC QUANTITIES   (ALL QUANTITIES FOR SINGLE HULL)
---------------------
   TOTAL DISPLACED VOLUME                                       =    0.184375E+05
   LOWER HULL DISPLACED VOLUME                                  =    0.149117E+05
   STRUT DISPLACED VOLUME                                       =    0.352585E+04
   LOWER HULL WETTED SURFACE AREA                               =    0.402559E+04
   STRUT WETTED SURFACE AREA                                    =    0.765500E+03

   CENTER OF BOUYANCY AT:                                 X     =    0.372267E+02
                                                          Y     =    0.299779E+02
                                                          Z     =   -0.102797E+02

   WATERPLANE AREA                                              =    0.714747E+03
   LONGITUDINAL CENTER OF FLOTATION, AFT OF FP                  =       39.845184
   LONGITUDINAL SECOND MOMENT OF WATERPLANE, ABOUT LCF          =    0.333577E+06
   TRANSVERSE SECOND MOMENT OF WATERPLANE, ABOUT X-AXIS         =    0.539983E+06

       •
       •
       •


    DO YOU WANT THE GRID NODAL POINTS COORDINATES PRINTED OUT?
     (Y/N, DEFAULT=Y)
  N

    *************
    SWATHGEN MENU
    *************

     ENTER YOUR CHOICE 1-7,  '8' TO PRINT MENU,  '0' TO STOP
    0
    BORTRAN STOP
    $
```

```
*******************************************
***  PANTHN -- THIN SHIP PANELIZATION  ***
*******************************************



ENTER THE DATA FILE NAME FOR THE PANEL DATA OUTPUT :
EXMPP2
ENTER THE FORM FACTORS FOR THE STRUT AND LOWER HULL, RESPECTIVELY
(ENTER 0 FOR DEFAULT)
0 0


*************
SWATHGEN MENU
*************

 ENTER YOUR CHOICE 1-7,  '8' TO PRINT MENU,  '0' TO STOP
4



================
SWPLOT EXECUTION
================

 -------------
 PLOTTING MENU
 -------------
          1) PLTALL: 3-D PLOTS OF THE HULL SURFACE
          2) PSEC: 2-D PLOTS OF THE ALPHA=CONSTANT GRID LINES
          3) PX: 2-D PLOTS OF X CROSS-SECTION CUTS THROUGH THE HULL SURFACE
          4) PZ: 2-D PLOTS OF WATERLINES

 ENTER 1,2,3, OR 4  (OR RETURN TO EXIT SWPLOT)


*************
SWATHGEN MENU
*************

 ENTER YOUR CHOICE 1-7,  '8' TO PRINT MENU,  '0' TO STOP
3


================
SWPRNT EXECUTION
================

 ENTER FILE NAME FOR DESCRIPTIVE PRINTOUT
  (ENTER 'TTY' FOR TERMINAL OUTPUT;  HIT RETURN FOR NO OUTPUT)
TTY
```

```
================
SWGRID EXECUTION
================
 GRID GENERATION COMPLETE


================
SWPROP EXECUTION
================
 HULL PROPERTIES CALCULATED


*************
SWATHGEN MENU
*************

 ENTER YOUR CHOICE 1-7,  '8' TO PRINT MENU,  '0' TO STOP
6

USER'S MANUAL EXAMPLE
 ENTER NEW HULL NAME (RETURN FOR NO CHANGE).
USER'S MANUAL EXAMPLE - 1ST OPTIMIZATION



*************
SWATHGEN MENU
*************

 ENTER YOUR CHOICE 1-7,  '8' TO PRINT MENU,  '0' TO STOP
5


==========
SWOUT MENU
==========
  1) WRITE DUPLICATE FILE OF STRUT DATA
  2) WRITE DUPLICATE FILE OF BOX DATA
  3) WRITE DUPLICATE FILE OF LOWER HULL DATA
  4) 1,2,AND 3 IN SEQUENCE
  5) WRITE SWCOMS DATA FILE FOR EXISTING HULL

ENTER CHOICE 1-5, '6' TO PRINT SWOUT MENU, RETURN TO EXIT SWOUT
5


 ENTER THE NAME OF THE SWCOMS DATA FILE, DEFAULT='SWCOMS.DAT'.
EXMPC2


ENTER CHOICE 1-5, '6' TO PRINT SWOUT MENU, RETURN TO EXIT SWOUT



*************
SWATHGEN MENU
*************

 ENTER YOUR CHOICE 1-7,  '8' TO PRINT MENU,  '0' TO STOP
```

7

```
=========
SWIN MENU
=========
  1) ENTER STRUT DATA
  2) ENTER BOX DATA
  3) ENTER LOWER HULL DATA
  4) 1,2,AND 3 IN SEQUENCE
  5) READ IN SWCOMS FILE FOR EXISTING HULL
  6) READ ONLY STRUT DATA FROM AN SWCOMS FILE
  7) READ ONLY BOX DATA FROM AN SWCOMS FILE
  8) READ ONLY LOWER HULL DATA FROM AN SWCOMS FILE
ENTER CHOICE 1-8,  RETURN TO EXIT SWIN
5


 ENTER THE NAME OF THE SWCOMS DATA FILE
EXMPC1


=========
SWIN MENU
=========
ENTER CHOICE 1-8, '9' TO PRINT SWIN MENU, RETURN TO EXIT SWIN
3

 ENTER LOWER HULL INPUT FILE NAME (RETURN FOR TERMINAL INPUT)
EXMPH2


=========
SWIN MENU
=========
ENTER CHOICE 1-8, '9' TO PRINT SWIN MENU, RETURN TO EXIT SWIN



==========
SWMOD MENU
==========
    NOTE:  THE VALUE '0' WILL LEAVE ANY VALUE UNCHANGED IN THE ROUTINE
           OR INVOKE A DEFAULT VALUE IF THE VARIABLE HAS NOT BEEN SET
           (ENTER 1.E-6 IF A ZERO VALUE IS REQUIRED.)

        1) MODIFY LOWER HULL ONLY
        2) MODIFY STRUT ONLY
        3) MODIFY BOX ONLY
        4) SET OR MODIFY FAIRING PARAMETERS
        5) CHANGE DESIGN WATERLINE
        6) RESCALE ENTIRE HULL CONFIGURATION
        7) PLOT UNFAIRED HULL CONFIGURATION
        8) RETURN TO SWATHGEN MENU

  ENTER SWMOD CHOICE 1-8, OR HIT RETURN TO RUN SWGRID
```

```
ALPHA, 'REASONABLENESS' COEFFICIENT                         0.20000E+01
WETTED SURFACE AREA OF ENTIRE HULL                        = 0.10804E+05
CENTER OF BUOYANCY ENTIRE HULL, FEET AFT OF FP            = 0.38526E+02
DISPLACED VOLUME OF ENTIRE HULL, CUBIC FEET                 0.34429E+05


RETURN TO WRITE SWATHGEN LOWER HULL INPUT FILE FOR THIS HULL,
ENTER 'Q' TO QUIT AND ENTER 'R' TO RERUN OPTVOL


ENTER THE NAME OF THE DATA FILE TO WHICH THE SWATHGEN LOWER HULL
INPUT DATA WILL BE WRITTEN:
EXMPH2
FORTRAN STOP
$
```

Now SWATHGEN is used to integrate the new lower hull with the old strut. By using the original SWCOMS file for input, the fairing parameters are read in automatically, along with the box, strut and original lower hull data. Then the lower hull data is superseded by the file created by OPTVOL, above. A new SWCOMS file is created, and a new thin ship/slender body panel data file is created.

```
$
$ SWATHGEN

 ENTER TERMINAL TYPE : 1 FOR TEKTRONIX, 2 FOR CIT-101:
2

*************
SWATHGEN MENU
*************
    1) SWIN (,SWMOD,SWGRID,SWPROP) - generate hull form
    2) SWMOD,SWGRID,SWPROP - modify hull form
    3) SWPRNT - descriptive printout
    4) SWPLOT - plots
    5) SWOUT - create SWCOMS output or DUPLICATE INPUT data files
    6) NAME OR RENAME HULL
    7) PANTHN - panelization for REPOW/OPTVOL input
 ENTER YOUR CHOICE 1-7, '0' TO STOP
1
```

>>>>> OPTVOL INPUT <<<<<

ENTER THE NAME OF THE SWATHGEN 'SWCOMS' FILE CONTAINING THE
ORIGINAL HULL DEFINITION:
EXMPC1

ENTER THE NAME OF THE DATA FILE CONTAINING THE STRUT SPECTRAL DATA
FOR THIS HULL CREATED BY REPOW :
EXMPK1

FROM THE REPOW CALCULATION FOR THE ORIGINAL HULL;
TOTAL VOLUME, FT^3 = 0.3443E+05
CENTER OF BUOYANCY, FT AFT FP = 0.3652E+02

ENTER THE NEW VOLUME AND CB, OR ENTER ZERO TO MAINTAIN THESE VALUES.
ENTER CB LESS THAN 0.0 TO REMOVE THE CENTER OF BUOYANCY CONSTRAINT:
0 -10
INPUT THE NUMBER OF SOURCE SEGMENTS DEFINING THE LOWER HULL (<40):
25
ENTER THE 'REASONABLENESS' COEFFICIENT, ALPHA :
2.

>>>> OPTVOL RESULTS <<<<

- OPTIMIZED HULL GEOMETRY FOR 0.3000E+02 FEET/SEC

X IS A COORDINATE ALONG THE HULL CENTERLINE, POSITIVE FWD

X, FEET	RADIUS, FEET
0.0000E+00	0.0000E+00
0.3932E+01	0.5430E+01
0.7864E+01	0.7028E+01
0.1180E+02	0.7822E+01
0.1573E+02	0.8145E+01
0.1966E+02	0.8150E+01
0.2359E+02	0.7931E+01
0.2752E+02	0.7562E+01
0.3146E+02	0.7109E+01
0.3539E+02	0.6637E+01
0.3932E+02	0.6212E+01
0.4325E+02	0.5899E+01
0.4718E+02	0.5752E+01
0.5112E+02	0.5801E+01
0.5505E+02	0.6034E+01
0.5898E+02	0.6412E+01
0.6291E+02	0.6873E+01
0.6684E+02	0.7357E+01
0.7078E+02	0.7801E+01
0.7471E+02	0.8150E+01
0.7864E+02	0.8342E+01
0.8257E+02	0.8309E+01
0.8650E+02	0.7958E+01
0.9044E+02	0.7139E+01
0.9437E+02	0.5511E+01
0.9830E+02	0.7099E-02

```
>>>> OPTVOL RESULTS <<<<

- OPTIMIZED HULL GEOMETRY FOR  0.3000E+02 FEET/SEC

 X IS A COORDINATE ALONG THE HULL CENTERLINE, POSITIVE FWD

        X, FEET         RADIUS, FEET
       0.0000E+00       0.0000E+00
       0.3932E+01       0.6279E+01
       0.7864E+01       0.8008E+01
       0.1180E+02       0.8756E+01
       0.1573E+02       0.8925E+01
       0.1966E+02       0.8696E+01
       0.2359E+02       0.8181E+01
       0.2752E+02       0.7466E+01
       0.3146E+02       0.6625E+01
       0.3539E+02       0.5736E+01
       0.3932E+02       0.4894E+01
       0.4325E+02       0.4228E+01
       0.4718E+02       0.3894E+01
       0.5112E+02       0.4001E+01
       0.5505E+02       0.4507E+01
       0.5898E+02       0.5261E+01
       0.6291E+02       0.6122E+01
       0.6684E+02       0.6985E+01
       0.7078E+02       0.7775E+01
       0.7471E+02       0.8428E+01
       0.7864E+02       0.8879E+01
       0.8257E+02       0.9050E+01
       0.8650E+02       0.8834E+01
       0.9044E+02       0.8052E+01
       0.9437E+02       0.6307E+01
       0.9830E+02       0.8022E-02

 ALPHA, 'REASONABLENESS' COEFFICIENT                    = 0.10000E+01
 WETTED SURFACE AREA OF ENTIRE HULL                     = 0.10789E+05
 CENTER OF BUOYANCY ENTIRE HULL, FEET AFT OF FP        = 0.38519E+02
 DISPLACED VOLUME OF ENTIRE HULL, CUBIC FEET            = 0.34428E+05


 RETURN TO WRITE SWATHGEN LOWER HULL INPUT FILE FOR THIS HULL,
 ENTER 'Q' TO QUIT AND ENTER 'R' TO RERUN OPTVOL
R
```

Recalling that the strut thickness was SLT=10 feet, it can be seen that the lower hull must have no radii less than 5 feet in the vincinity of the strut. To that end, OPTVOL is rerun below, with the parameter alpha set to 2.0 instead of 1.0 . This limits the variation of source strengths and produces a smoother hull.

```
ENTER YOUR MENU CHOICE (7 FOR MENU, 8 TO STOP):
3


        OPTVOL INPUT GENERATION


 ENTER THE SHIP SPEED FOR THE OPTIMIZATION IN FEET/SECOND:
30
    . WORKING ON PANEL    8  OUT OF 145 FOR  30.00 FT/S

      SPECIFY THE NAME OF THE DATA FILE FOR THE SPECTRAL DATA OUTPUT:

EXMPR1

ENTER YOUR MENU CHOICE (7 FOR MENU, 8 TO STOP):


8
FORTRAN STOP
$
$ RUN
```

Now OPTVOL is run to find the lower hull form which will best reduce the wave resistance .

```
$   OPTVOL

>>>>> OPTVOL INPUT <<<<<


 ENTER THE NAME OF THE SWATHGEN 'SWCOMS' FILE CONTAINING THE
ORIGINAL HULL DEFINITION:
EXMPC1


 ENTER THE NAME OF THE DATA FILE CONTAINING THE STRUT SPECTRAL DATA
FOR THIS HULL CREATED BY REPOW :
EXMPR1


 FROM THE REPOW CALCULATION FOR THE ORIGINAL HULL:
                TOTAL VOLUME, FT^3  = 0.3443E+05
     CENTER OF BUOYANCY, FT AFT FP = 0.3652E+02

 ENTER THE NEW VOLUME AND CB, OR ENTER ZERO TO MAINTAIN THESE VALUES.
ENTER CB LESS THAN 0.0 TO REMOVE THE CENTER OF BUOYANCY CONSTRAINT:
0 -10
 INPUT THE NUMBER OF SOURCE SEGMENTS DEFINING THE LOWER HULL (<40):
25
 ENTER THE 'REASONABLENESS' COEFFICIENT, ALPHA :
1
```

```
><><><><><>< REPOW  --  SWATH RESISTANCE AND POWERING><><><><><

         >>>>>>>>>MAIN MENU<<<<<<<<<

     1) READ IN SWATH PANEL DATA

     2) THREE-DIMENSIONAL PLOTS OF THE HULL PANELS

     3) CALCULATE THE FREE SURFACE SPECTRAL FUNCTION
        (FOR OPTVOL INPUT, STRUT DATA ONLY)
     4) CALCULATE RESISTANCE VERSUS SPEED

     5) PLOT RESISTANCE VERSUS SPEED

     6) OUTPUT RESISTANCE VERSUS SPEED

     7) RETYPE THIS MENU

     8) STOP


ENTER YOUR MENU CHOICE (7 FOR MENU, 8 TO STOP):
1


>>>>>> PANEL DATA INPUT <<<<<<
SPECIFY THE NAME OF THE DATA FILE FROM WHICH THIS
PROGRAM WILL READ THE THIN SHIP PANEL INPUT DATA:
(RETURN TO QUIT)
EXMPP1


>>>> PANEL VOLUME CHECK <<<<

     WORKING ON PANEL 168  WORKING168 PANEL 0600 0F78OF 168 FOR   0.00 FT/S

>>> PANEL DATA INPUT VERIFICATION <<<
USER'S MANUAL EXAMPLE
PANEL DATA READ FROM THE FILE : EXMPP1
                                 STRUT       LOWER HULL       TOTAL
            NUMBER OF PANELS      145            23            168
            NUMBER OF POINTS      165            36            201
                 FORM FACTOR     1.170         1.100           ---
       EFFECTIVE LENGTH, FT  0.8478E+02    0.1000E+03          ---
SURFACE AREA, 2 HULLS, FT^2  0.2082E+04    0.7763E+04    0.9845E+04

 >>> SOURCE DISTRIBUTION PROPERTIES -- TWO HULLS
       DISPLACED VOLUME, FT^3...0.3443E+05
             LCB, FT AFT OF FP...0.3652E+02
NET NORMALIZED SOURCE STRENGTH...0.1322E+00
```

```
*************
SWATHGEN MENU
*************

 ENTER YOUR CHOICE 1-7,  '8' TO PRINT MENU,  '0' TO STOP
7


*******************************************
***  PANTHN -- THIN SHIP PANELIZATION  ***
*******************************************



ENTER THE DATA FILE NAME FOR THE PANEL DATA OUTPUT :
EXMPP1
ENTER THE FORM FACTORS FOR THE STRUT AND LOWER HULL, RESPECTIVELY
(ENTER 0 FOR DEFAULT)
0 0


*************
SWATHGEN MENU
*************

 ENTER YOUR CHOICE 1-7,  '8' TO PRINT MENU,  '0' TO STOP
0

FORTRAN STOP
$
```

Now REPOW is run to create the free-surface spectrum due to the strut alone, for input to OPTVOL.

I = 3

J	X	Y	Z
11	-5.259715	29.156794	-7.840264
12	-5.281854	26.326027	-9.108628
13	-5.321218	24.864618	-11.363737
14	-5.364892	25.252014	-13.965753
15	-5.398546	27.361122	-15.793843
16-17	-5.411143	30.499998	-16.515450
18	-5.394269	34.077484	-15.548754
19	-5.351065	36.082672	-13.073521
20	-5.300515	35.634293	-10.177612
21	-5.264839	32.929401	-8.135777
22	-5.259715	29.156794	-7.840264

I = 4

J	X	Y	Z
11	-1.913018	28.907154	-7.103710
12	-1.939272	25.350276	-8.607805
13	-1.985951	23.817259	-11.282035
14	-2.037742	24.276653	-14.249063

•
•
•

I = 36 TAIL - STRUT OVERHANG TRAILING EDGE

J	X	Y	Z
1	91.802643	25.374434	10.000005
2	91.118973	26.180569	6.207436
3	90.435310	26.986704	2.414867
4	89.751640	27.792839	-1.377701
5	89.067963	28.598974	-5.170270
11	87.984764	30.500000	-13.745237
12	87.984764	30.500000	-13.745237
13	87.984764	30.500000	-13.745237
14	87.984764	30.500000	-13.745237
15	87.984764	30.500000	-13.745237
16-17	87.984764	30.500000	-13.745237
18	87.984764	30.500000	-13.745237
19	87.984764	30.500000	-13.745237
20	87.984764	30.500000	-13.745237
21	87.984764	30.500000	-13.745237
22	87.984764	30.500000	-13.745237
28	89.067963	28.598974	-5.170270
29	89.751640	27.792839	-1.377701
30	90.435310	26.986704	2.414867
31	91.118973	26.180569	6.207436
32	91.802643	25.374434	10.000005

```
THE J'S CORRESPOND TO REGIONS OF THE HULL SURFACE AS FOLLOWS:
     INBOARD STRUT SURFACE                           1 < J <  5
     INBOARD STRUT-HULL FAIRING                      6 < J < 10
     INBOARD HULL SURFACE                           11 < J < 16
     OUTBOARD HULL SURFACE                          17 < J < 22
     OUTBOARD HULL-STRUT FAIRING                    23 < J < 27
     OUTBOARD STRUT SURFACE                         28 < J < 32



DO YOU WANT THE GRID NODAL POINTS COORDINATES PRINTED OUT?
 (Y/N, DEFAULT=Y)
Y


COORDINATES
-----------
NOTE: *** INDICATES A DISCONTINUOUS SURFACE NORMAL ACROSS
      THE J PANEL EDGE
```

I = 1 NOSE

J	X	Y	Z
11	-12.000005	30.499998	-11.999997
12	-12.000005	30.499998	-11.999997
13	-12.000005	30.499998	-11.999997
14	-12.000005	30.499998	-11.999997
15	-12.000005	30.499998	-11.999997
16-17	-12.000005	30.499998	-11.999997
18	-12.000005	30.499998	-11.999997
19	-12.000005	30.499998	-11.999997
20	-12.000005	30.499998	-11.999997
21	-12.000005	30.499998	-11.999997
22	-12.000005	30.499998	-11.999997

I = 2

J	X	Y	Z
11	-8.612778	29.520979	-8.941467
12	-8.628915	27.457722	-9.865940
13	-8.657603	26.392546	-11.509618
14	-8.689437	26.674906	-13.333261
15	-8.713967	28.212166	-14.738584
16-17	-8.723147	30.499998	-15.264544
18	-8.710850	33.107513	-14.559948
19	-8.679360	34.569035	-12.755826
20	-8.642515	34.242226	-10.645088
21	-8.616511	32.270714	-9.155396
22	-8.612778	29.520979	-8.941467

```
$ TY EXMPT1.DAT


>>>>>>  REPOW RESISTANCE AND POWERING PROGRAM OUTPUT <<<<<<
USER'S MANUAL EXAMPLE


>>> PANEL DATA INPUT VERIFICATION <<<

                                  STRUT       LOWER HULL    APPENDAGES      TOTAL
          NUMBER OF PANELS          145           23            ---          168
          NUMBER OF POINTS          165           36            ---          201
               FORM FACTOR        1.170        1.100            ---          ---
      EFFECTIVE LENGTH, FT   0.8478E+02   0.1000E+03            ---          ---
SURFACE AREA, 2 HULLS, FT^2  0.2082E+04   0.7763E+04     0.0000E+00   0.9845E+04


 >>> SOURCE DISTRIBUTION PROPERTIES -- TWO HULLS
        DISPLACED VOLUME, FT^3...0.3443E+05
      DISPLACEMENT, LONG TONS...0.9843E+03
              LCB, FT AFT OF FP...0.3652E+02
NET NORMALIZED SOURCE STRENGTH...0.1322E+00


 KINEMATIC VISCOSITY, FT/SEC^2 = 0.1279E-04
           DENSITY, SLUG/FT^3 = 0.1990E+01
      CORRELATION ALLOWANCE = 0.5000E-03


*** NO APPENDAGES
```

SPEED, FT/S	SPEED, KT	SPEED/LENGTH RATIO	FROUDE #	EHP
15.00	8.88	0.888	0.264	0.6557E+03
16.00	9.47	0.947	0.282	0.1083E+04
17.00	10.07	1.007	0.300	0.1346E+04
18.00	10.66	1.066	0.317	0.1317E+04
20.00	11.84	1.184	0.353	0.1304E+04
22.00	13.03	1.303	0.388	0.2705E+04
24.00	14.21	1.421	0.423	0.5369E+04
26.00	15.39	1.539	0.458	0.8356E+04
28.00	16.58	1.658	0.494	0.1102E+05
30.00	17.76	1.776	0.529	0.1313E+05
33.00	19.54	1.954	0.582	0.1533E+05
36.00	21.31	2.131	0.635	0.1672E+05
40.00	23.68	2.368	0.705	0.1791E+05
44.00	26.05	2.605	0.776	0.1884E+05
49.00	29.01	2.901	0.864	0.1997E+05

SPEED, FT/S	RT, LB	CT	RR, LB	CR
15.00	0.2404E+05	0.1091E-01	0.1791E+05	0.8124E-02
16.00	0.3721E+05	0.1484E-01	0.3029E+05	0.1208E-01
17.00	0.4356E+05	0.1538E-01	0.3580E+05	0.1264E-01
18.00	0.4024E+05	0.1268E-01	0.3160E+05	0.9953E-02
20.00	0.3587E+05	0.9152E-02	0.2533E+05	0.6462E-02
22.00	0.6762E+05	0.1426E-01	0.5500E+05	0.1160E-01
24.00	0.1230E+06	0.2180E-01	0.1082E+06	0.1916E-01
26.00	0.1768E+06	0.2669E-01	0.1595E+06	0.2407E-01
28.00	0.2164E+06	0.2817E-01	0.1965E+06	0.2558E-01
30.00	0.2406E+06	0.2729E-01	0.2180E+06	0.2472E-01
33.00	0.2555E+06	0.2394E-01	0.2283E+06	0.2140E-01
36.00	0.2555E+06	0.2012E-01	0.2235E+06	0.1760E-01
40.00	0.2463E+06	0.1571E-01	0.2072E+06	0.1322E-01
44.00	0.2355E+06	0.1241E-01	0.1897E+06	0.9946E-02
49.00	0.2241E+06	0.9527E-02	0.1668E+06	0.7089E-02

SPEED, FT/S	RF,LB	CF	RFS,LB	CFS
15.00	0.6133E+04	0.2782E-02	0.1137E+04	0.2440E-02
16.00	0.6926E+04	0.2761E-02	0.1282E+04	0.2417E-02
17.00	0.7763E+04	0.2742E-02	0.1435E+04	0.2396E-02
18.00	0.8646E+04	0.2723E-02	0.1595E+04	0.2376E-02
20.00	0.1055E+05	0.2691E-02	0.1940E+04	0.2341E-02
22.00	0.1262E+05	0.2662E-02	0.2316E+04	0.2310E-02
24.00	0.1487E+05	0.2636E-02	0.2723E+04	0.2282E-02
26.00	0.1730E+05	0.2612E-02	0.3160E+04	0.2256E-02
28.00	0.1990E+05	0.2591E-02	0.3627E+04	0.2233E-02
30.00	0.2267E+05	0.2571E-02	0.4124E+04	0.2212E-02
33.00	0.2715E+05	0.2544E-02	0.4926E+04	0.2183E-02
36.00	0.3200E+05	0.2520E-02	0.5793E+04	0.2157E-02
40.00	0.3906E+05	0.2492E-02	0.7050E+04	0.2127E-02
44.00	0.4679E+05	0.2467E-02	0.8421E+04	0.2100E-02
49.00	0.5737E+05	0.2439E-02	0.1029E+05	0.2070E-02

SPEED, FT/S	RFH,LB	CFH	RAPP, LB	RCORR, LB
15.00	0.3894E+04	0.2240E-02	0.0000E+00	0.1102E+04
16.00	0.4390E+04	0.2219E-02	0.0000E+00	0.1254E+04
17.00	0.4913E+04	0.2200E-02	0.0000E+00	0.1416E+04
18.00	0.5463E+04	0.2182E-02	0.0000E+00	0.1587E+04
20.00	0.6646E+04	0.2150E-02	0.0000E+00	0.1960E+04
22.00	0.7935E+04	0.2122E-02	0.0000E+00	0.2371E+04
24.00	0.9330E+04	0.2096E-02	0.0000E+00	0.2822E+04
26.00	0.1083E+05	0.2073E-02	0.0000E+00	0.3312E+04
28.00	0.1243E+05	0.2052E-02	0.0000E+00	0.3841E+04
30.00	0.1414E+05	0.2033E-02	0.0000E+00	0.4409E+04
33.00	0.1689E+05	0.2007E-02	0.0000E+00	0.5335E+04
36.00	0.1986E+05	0.1983E-02	0.0000E+00	0.6349E+04
40.00	0.2418E+05	0.1956E-02	0.0000E+00	0.7839E+04
44.00	0.2888E+05	0.1931E-02	0.0000E+00	0.9485E+04
49.00	0.3531E+05	0.1904E-02	0.0000E+00	0.1176E+05

```
*** ST = TOTAL SURFACE AREA - STRUT + LOWER HULLS + APPENDAGES
*** SH = LOWER HULL UNAPPENDED SURFACE AREA
*** SS = STRUT UNAPPENDED SURFACE AREA
*** SA = TOTAL APPENDAGE AREA
*** FROUDE NUMBER BASED ON LOWER HULL LENGTH
*** EHP = EFFECTIVE HORSEPOWER
*** RT = TOTAL RESISTANCE
*** CT = COEFFICIENT OF TOTAL RESISTANCE = RT/(.5*RHO*ST*V**2)
*** RR = WAVE RESISTANCE
*** CR = WAVE RESISTANCE COEFFICIENT = RR/(.5*RHO*ST*V**2)
*** RF = STRUT AND HULL FRICTIONAL RESISTANCE = RFS+RFH+RCOR
*** CF = FRICTIONAL RESISTANCE COEFFICIENT = RF/(.5*RHO*ST*V**2)
*** RFS = STRUT FRICTIONAL RESISTANCE
*** CFS = STRUT FRICTIONAL RESISTANCE COEFFICIENT = RFS/(.5*RHO*SS*V**2)
*** RFH = LOWER HULL FRICTIONAL RESISTANCE
*** CFH = LOWER HULL FRICTIONAL RESISTANCE COEFFICIENT = RFH/(.5*RHO*SH*V**2)
*** RAPP = APPENDAGE RESISTANCE - ALL SOURCES
*** RCOR = CORRELATION ALLOWANCE
```

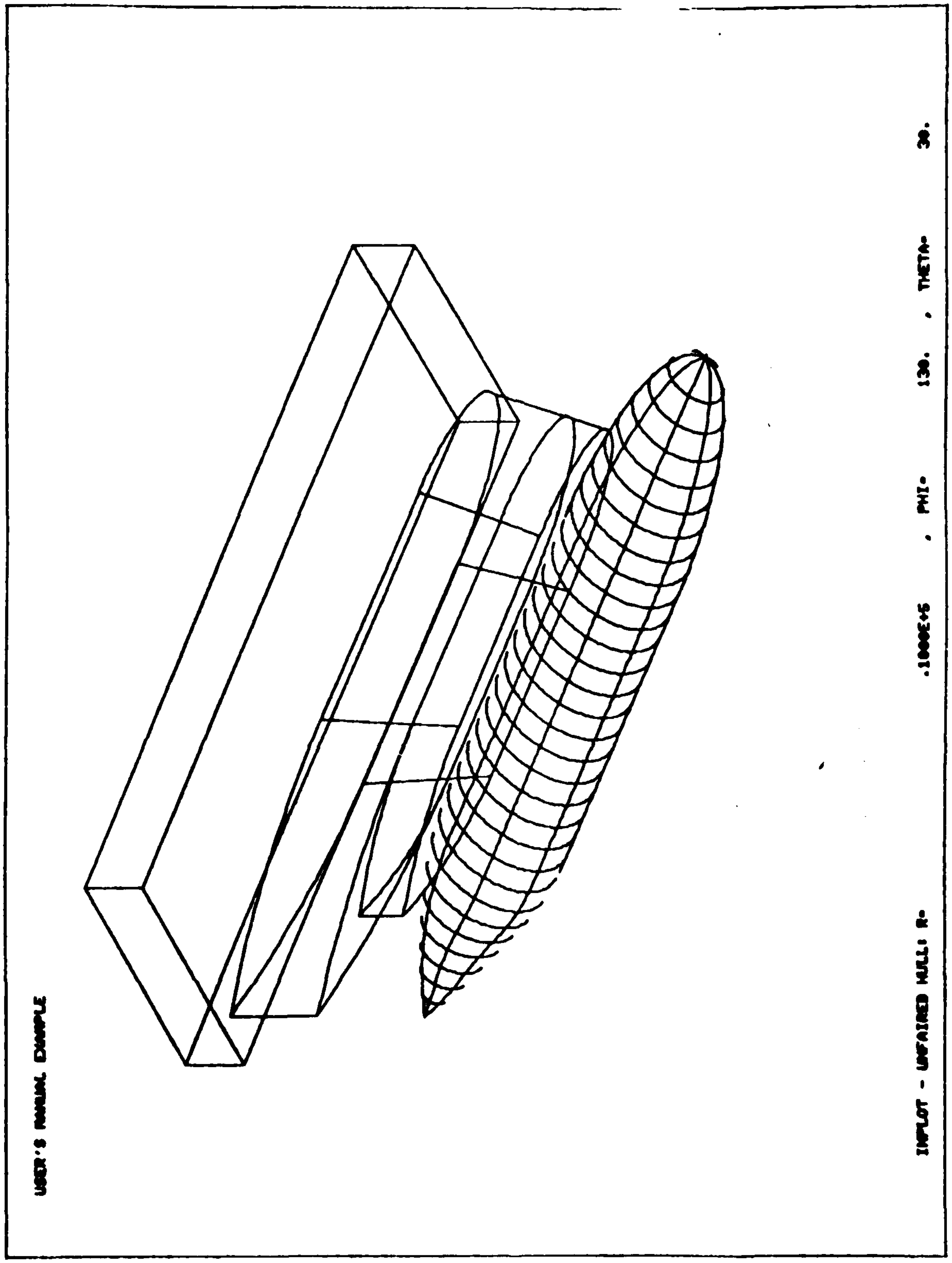

Figure C-1. Unfaired Hull, Original Form.

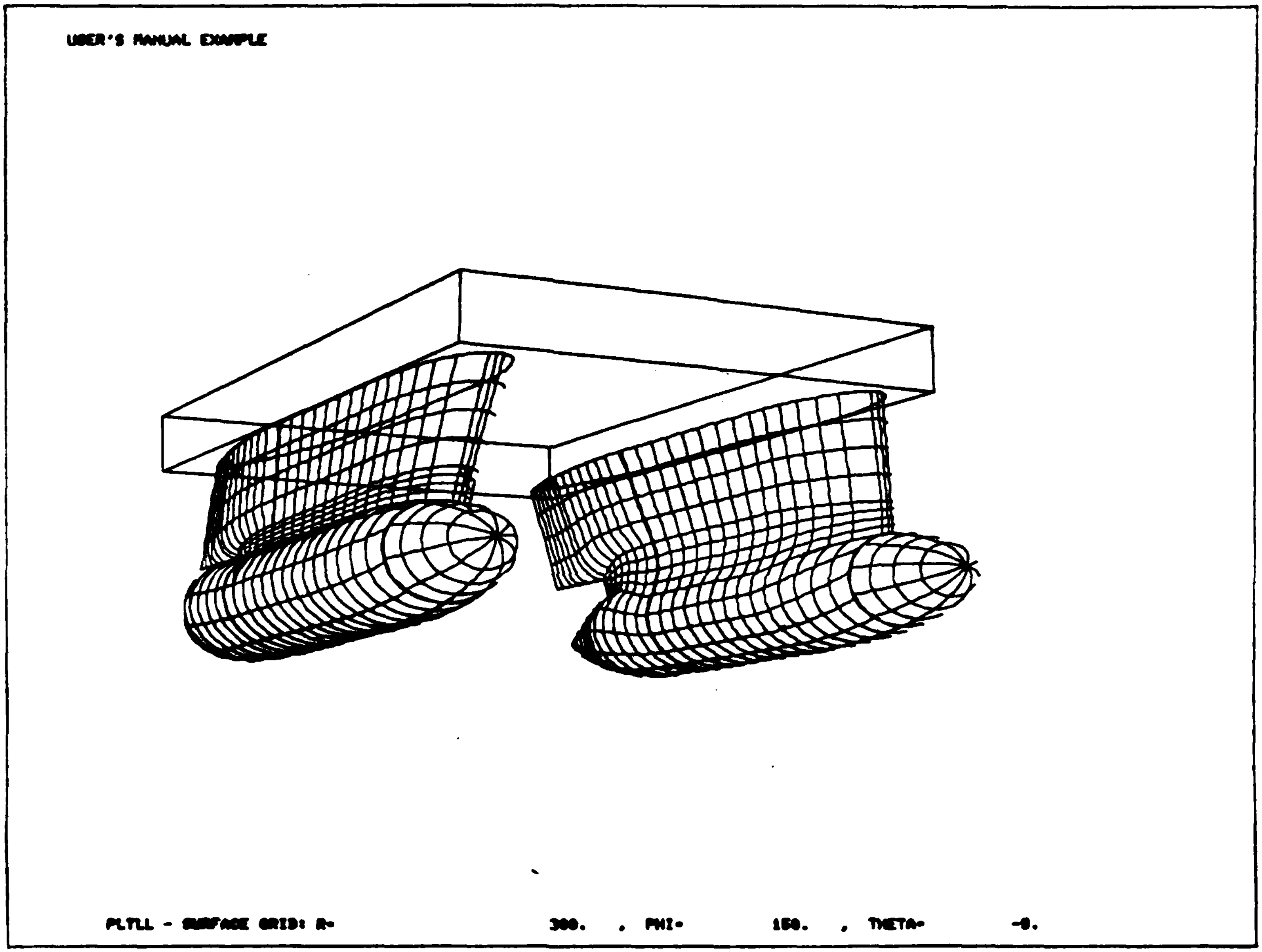

Figure C-2. Faired Hull (looking aft) Original Form.

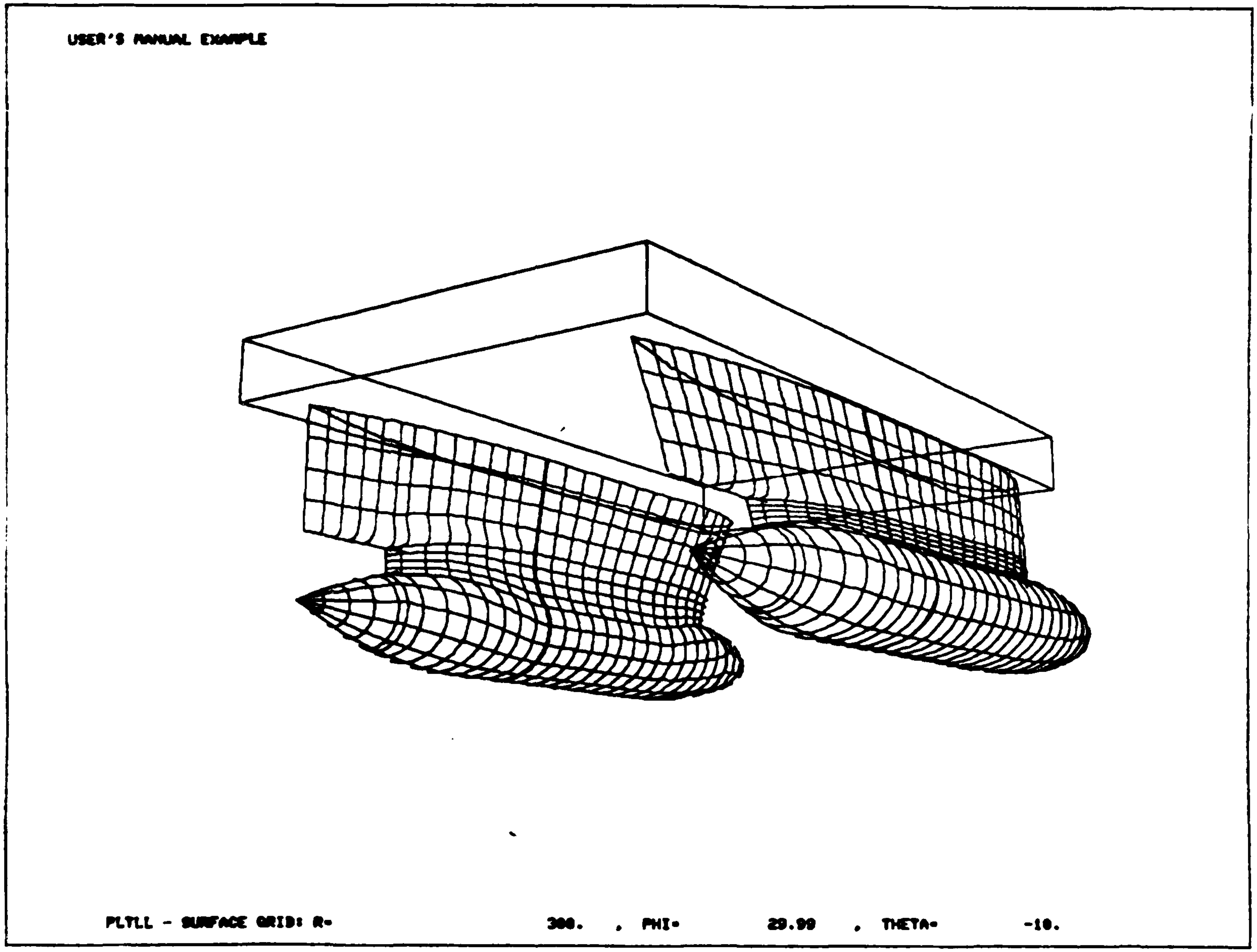

Figure C-3. Faired Hull (looking fwd) Original Form.

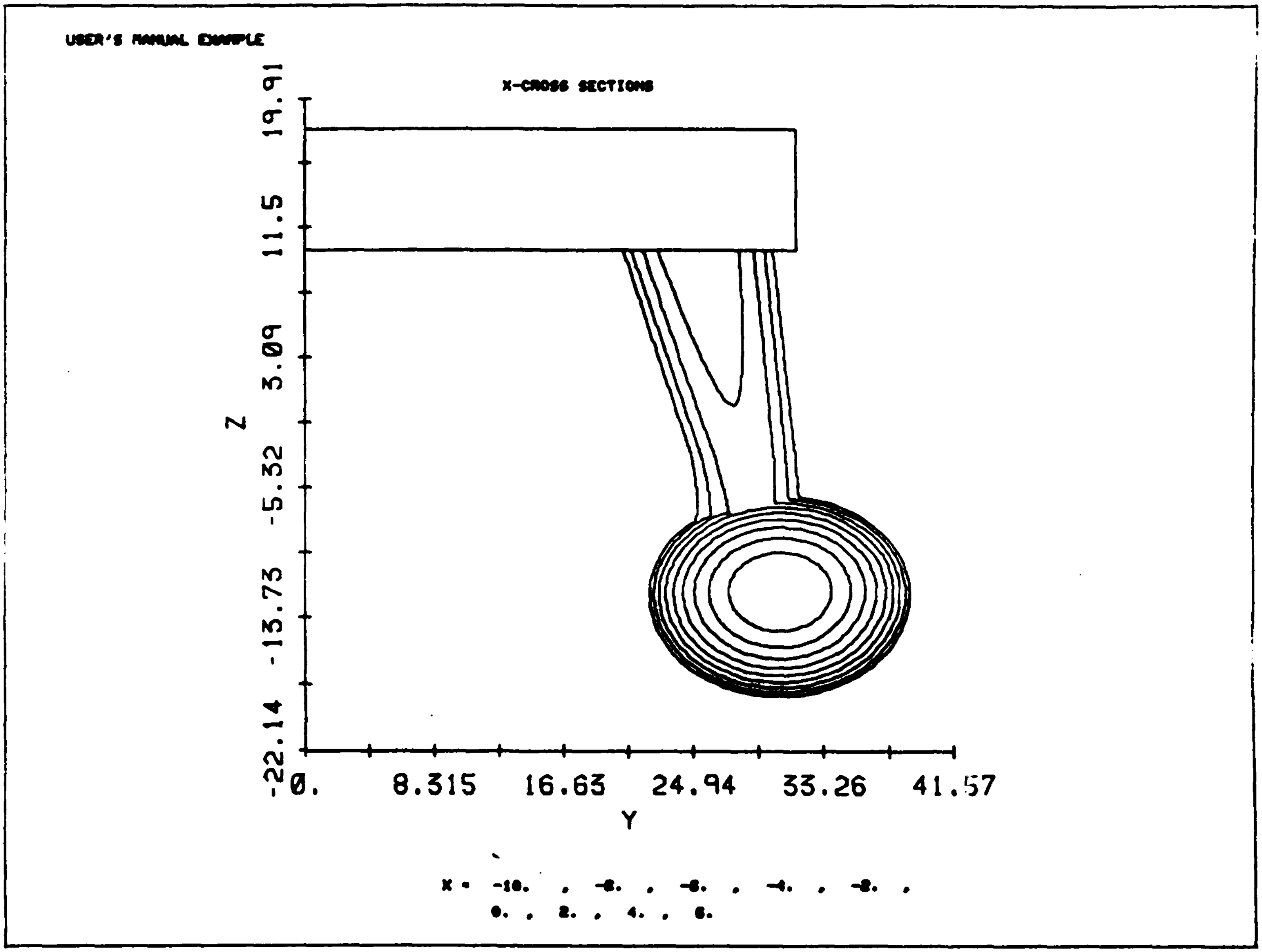

Figure C-4. X-cross Sections at the Nose, Original Form.

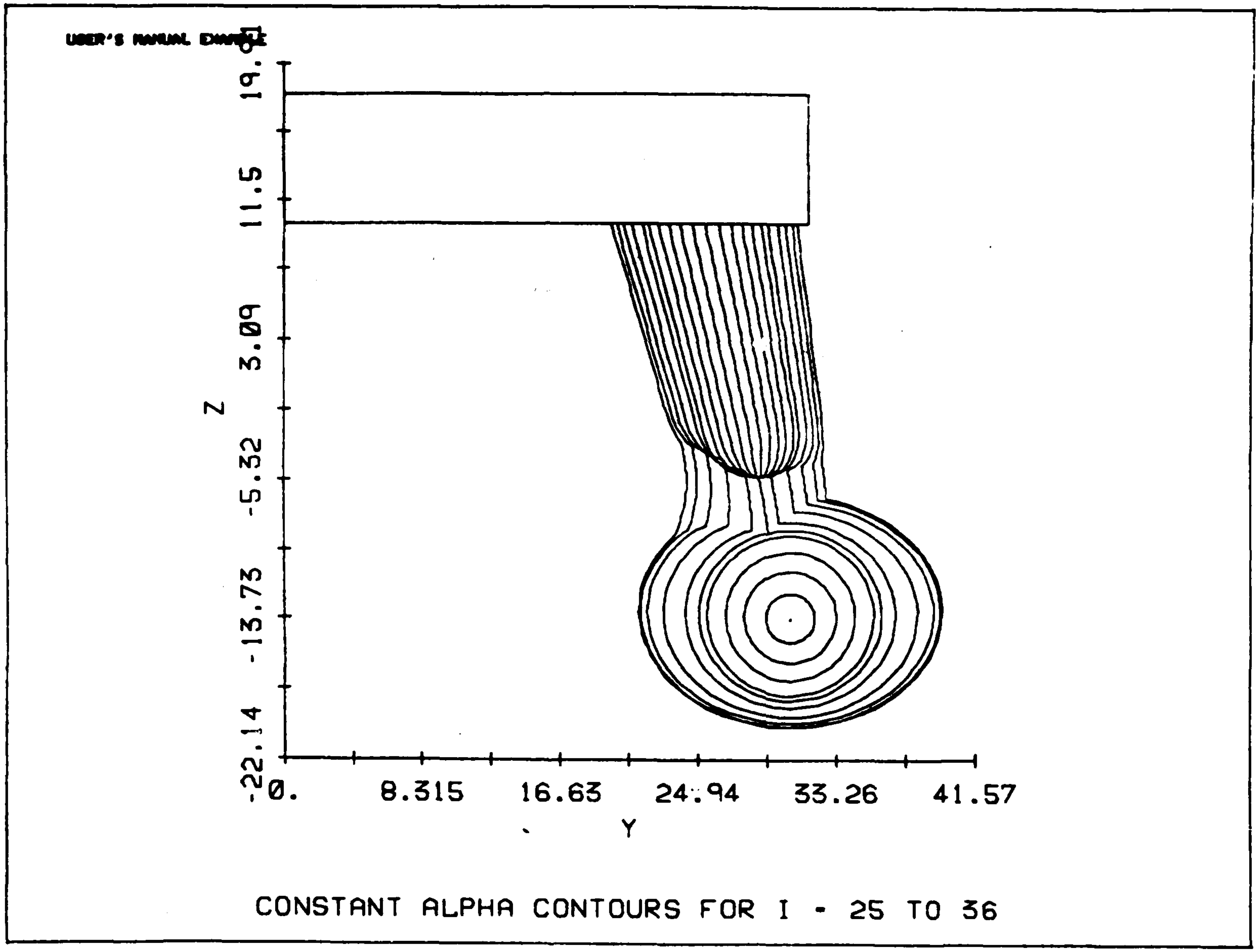

Figure C-5. Constant Alpha Contours in Way of the Overhang, Original Form.

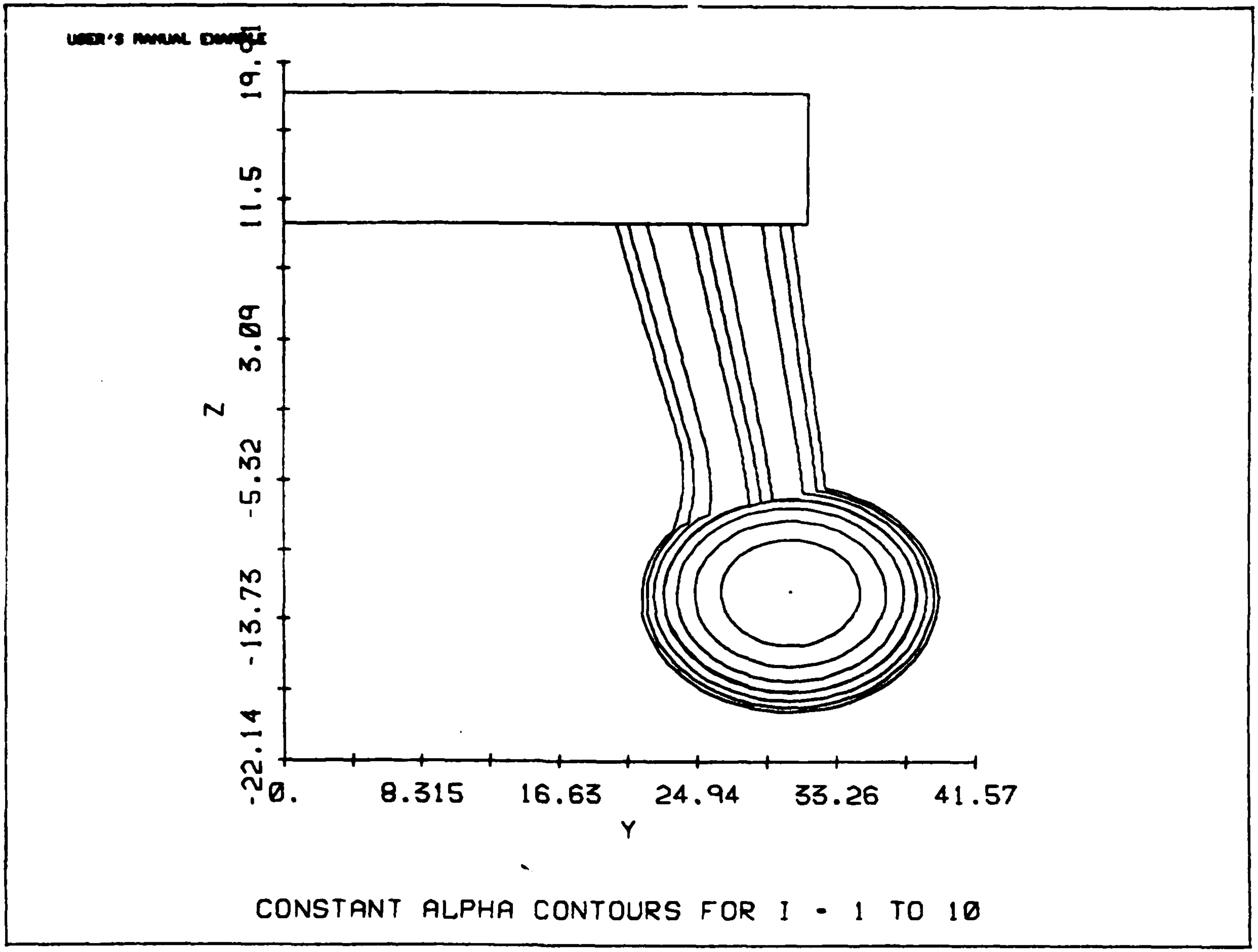

Figure C-6. Constant Alpha Contours at the Nose Original Form.

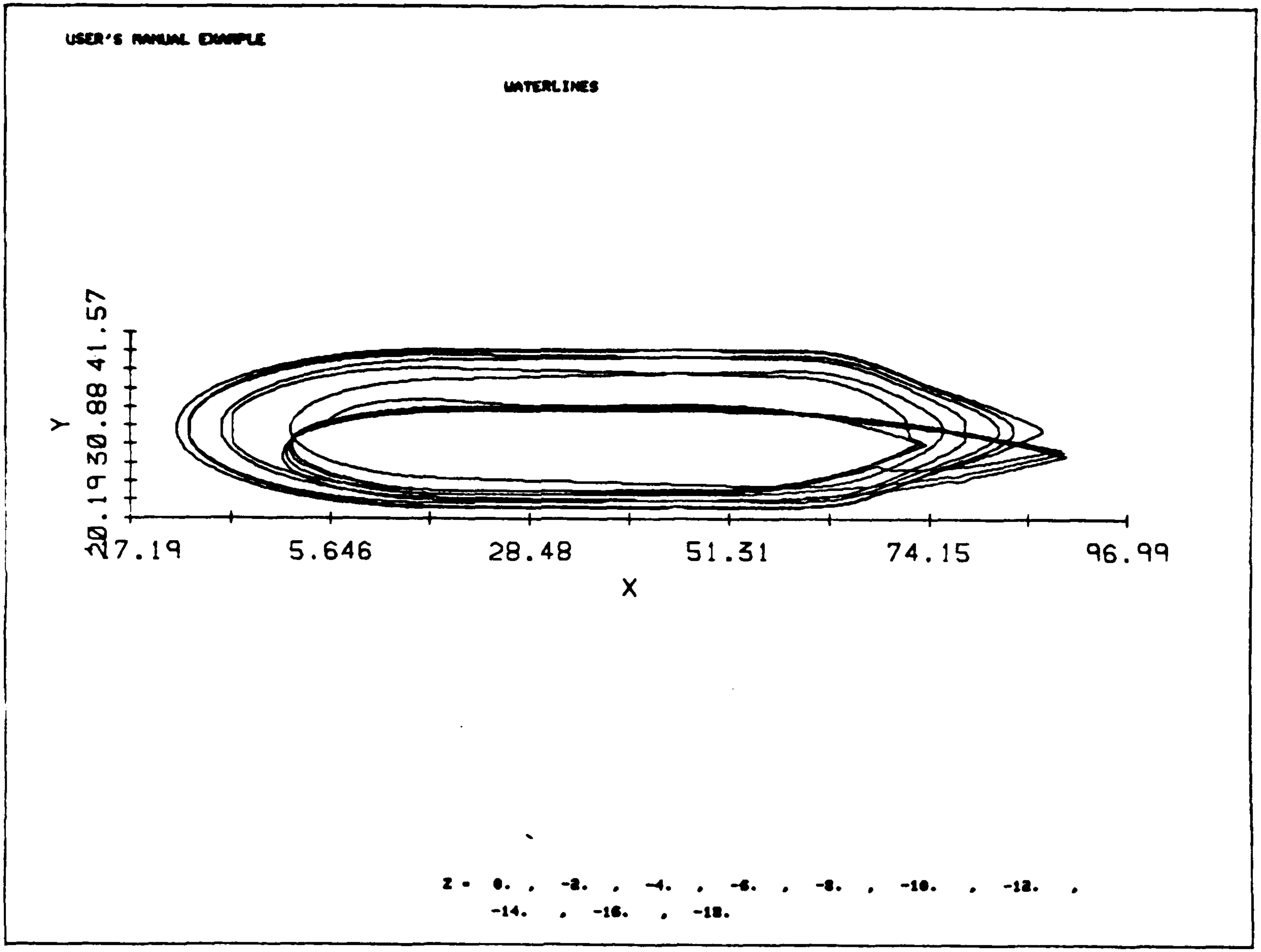

Figure C-7. Waterlines, Original Form.

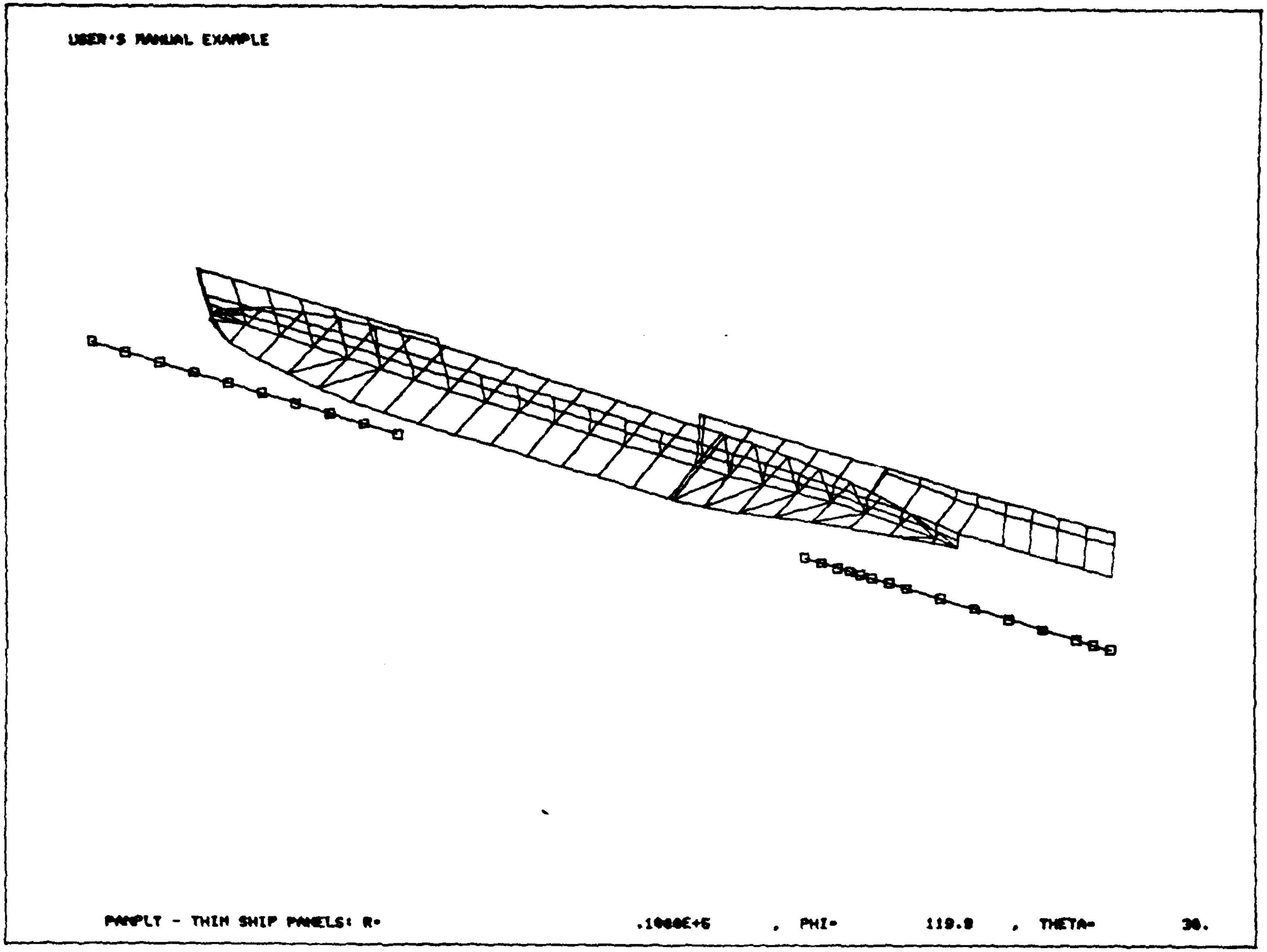

Figure C-8. Source Panels Original Form.

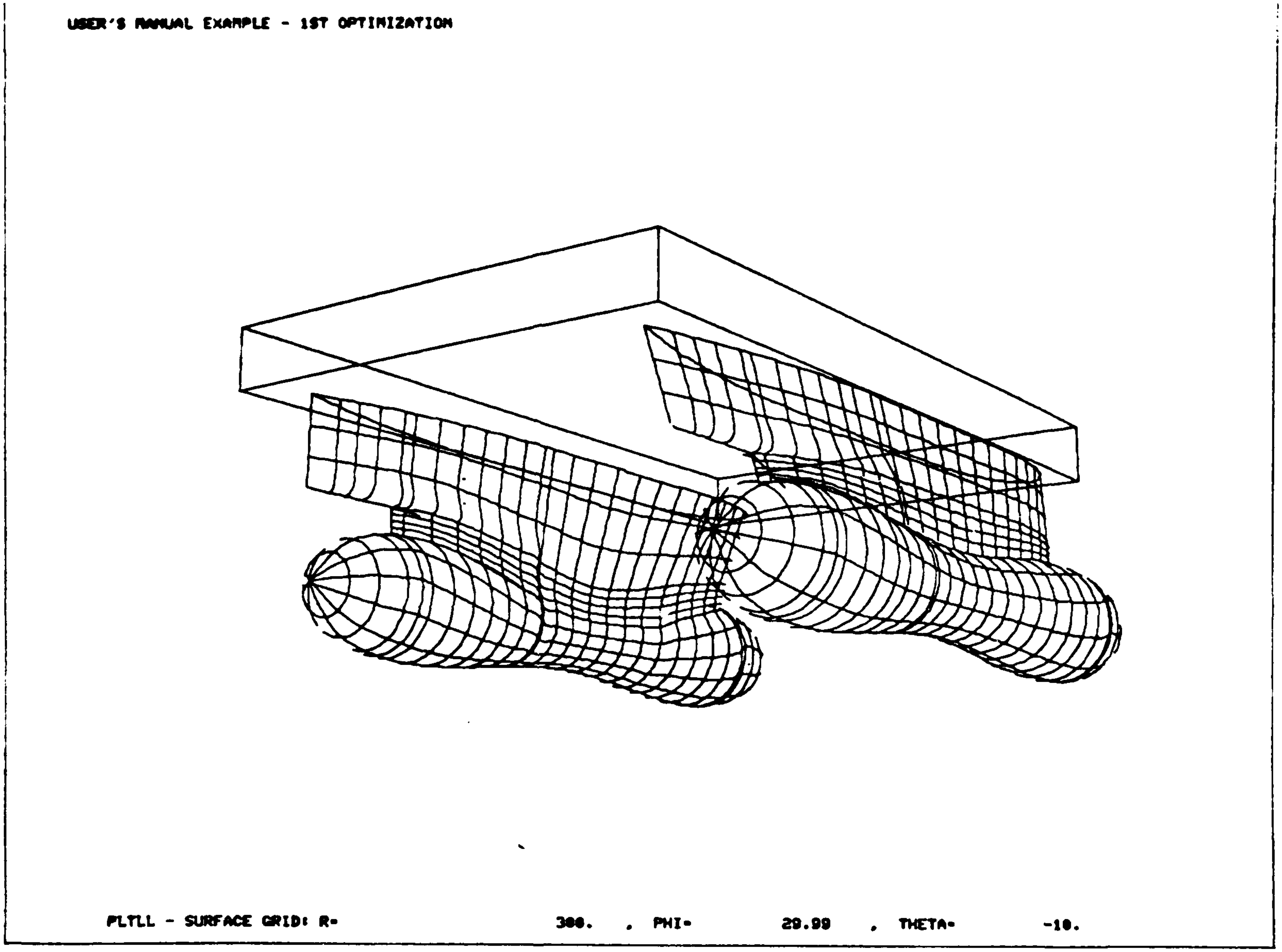

Figure C-9. Faired Hull (looking fwd) Optimized Form.

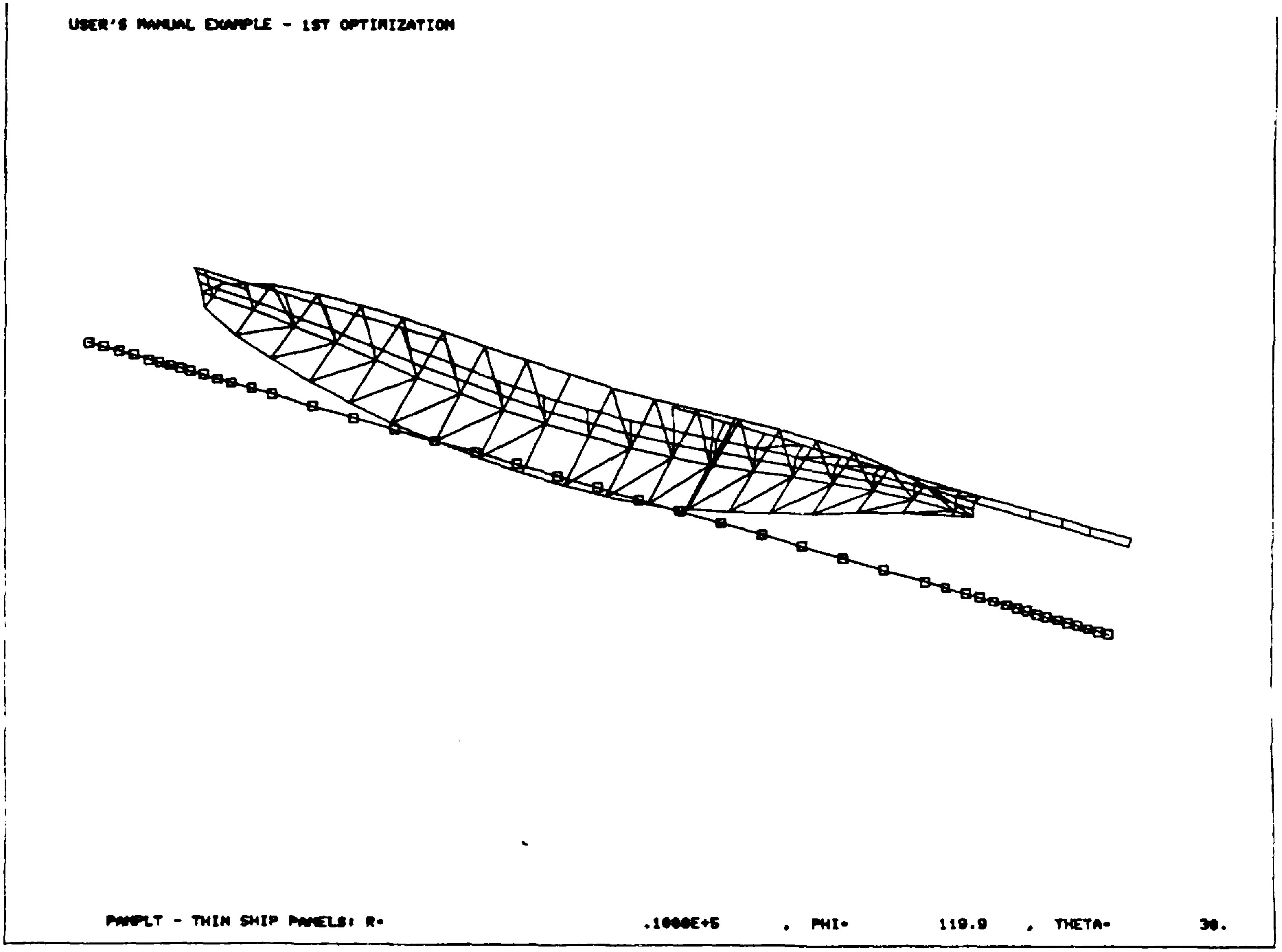

Figure C-10. Source Panels, Optimized Form.

FAIRING SECTIONS

SECTION	INBOARD SECTION TYPE	INBOARD CONSTRUCTION ROUTINE	INBOARD FAIRING RADIUS	OUTBOARD SECTION TYPE	OUTBOARD CONSTRUCTION ROUTINE	OUTBOARD FAIRING RADIUS
5	LE/TE	F7	0.00000	LE/TE	F7	0.00000
6	TRANS	F8	6.45185	TRANS	F8	6.45264
7	TRANS	F8	3.25187	TRANS	F8	3.25217
8	TRANS	F8	2.18476	TRANS	F8	2.18488
9	TRANS	F8	1.64714	TRANS	F8	1.64722
10	TRANS	F8	1.32265	TRANS	F8	1.32270
11	TRANS	F8	1.10636	TRANS	F8	1.10630
12	TRANS	F8	0.95318	TRANS	F8	0.95320
13	TRANS	F8	0.84089	TRANS	F8	0.84086
14	TRANS	F8	0.75693	TRANS	F8	0.75693
15	TRANS	F8	0.69379	TRANS	F8	0.69380
16	TRANS	F8	0.64655	TRANS	F8	0.64654
17	TRANS	F8	0.61048	TRANS	F8	0.61048
18	TRANS	F8	0.58351	TRANS	F8	0.58351
19	TRANS	F8	0.56313	TRANS	F8	0.56313
20	TRANS	F8	0.54720	TRANS	F8	0.54720
21	TRANS	F8	0.53389	TRANS	F8	0.53389
22	TRANS	F8	0.52171	TRANS	F8	0.52171
23	TRANS	F8	0.50962	TRANS	F8	0.50962
24	MID	F6	0.50000	MID	F6	0.50000
25	MID	F6	0.50000	MID	F6	0.50000
26	MID	F6	0.50000	MID	F6	0.50000
27	TRANS	F8	0.51919	TRANS	F8	0.51919
28	TRANS	F8	0.57406	TRANS	F8	0.57405
29	TRANS	F8	0.71044	TRANS	F8	0.71043
30	TRANS	F8	1.13407	TRANS	F8	1.13405
31	TRANS	F8	3.51115	TRANS	F8	3.50995
32	LE/TE	F7	0.00000	LE/TE	F7	0.00000

SURFACE GRID DATA

STRUT DISPLACED VOLUME		=	0.101258E+03
LOWER HULL WETTED SURFACE AREA		=	0.105665E+05
STRUT WETTED SURFACE AREA		=	0.385647E+04
CENTER OF BOUYANCY AT:	X	=	0.105461E+03
	Y	=	0.385009E+02
	Z	=	-0.134783E+02
WATERPLANE AREA		=	0.107457E+04
LONGITUDINAL CENTER OF FLOTATION, AFT OF FP		=	106.413475
LONGITUDINAL SECOND MOMENT OF WATERPLANE, ABOUT LCF		=	0.266509E+07
TRANSVERSE SECOND MOMENT OF WATERPLANE, ABOUT X-AXIS		=	0.159607E+07

STRUT-LOWER HULL FAIRING PARAMETERS

OUTBOARD FAIRING METHOD		=	1
LE/TE FAIRING METHOD		=	1
DELTA R (LE)		=	0.500000
DELTA R (TE)		=	0.500000
LE Y-OFFSET FROM LOWER HULL CENTERLINE		=	0.000000
TE Y-OFFSET FROM LOWER HULL CENTERLINE		=	0.000000
MAXIMUM INBOARD FAIRING HEIGHT AT:	X	=	84.370140
	Y	=	35.381340
	Z	=	-8.822274
MAXIMUM OUTBOARD FAIRING HEIGHT AT:	X	=	84.370140
	Y	=	41.618660
	Z	=	-8.822274
MID-SECTION BOUNDARY POSITIONS:	XOF	=	0.000000
	XOA	=	0.000000
	XIF	=	0.000000
	XIA	=	0.000000

FINAL RADII DISTRIBUTION

X	R	dR/dX	CEL	AREA
0.000000	0.000000	**********	1.800000	0.000000
8.153846	2.519807	0.148336	1.800000	35.905174
16.307692	3.491548	0.098131	1.800000	68.937958
24.461538	4.186219	0.074406	1.800000	99.098312
32.615383	4.727578	0.059297	1.800000	126.386238
40.769230	5.164069	0.048254	1.800000	150.801773
48.923077	5.520622	0.039495	1.800000	172.344894
57.076923	5.811968	0.032156	1.800000	191.015579
65.230766	6.047538	0.025753	1.800000	206.813858
73.384613	6.233660	0.019987	1.800000	219.739716
81.538460	6.374665	0.014659	1.800000	229.793182
89.692307	6.473503	0.009623	1.800000	236.974182
97.846153	6.532088	0.004768	1.800000	241.282837
106.000000	6.551500	0.000000	1.800000	242.719040
114.362503	6.551500	0.000000	1.800000	242.719040
122.724998	6.551500	0.000000	1.800000	242.719040
131.087509	6.551500	0.000000	1.800000	242.719040
139.449997	6.551500	0.000000	1.800000	242.719040
147.812500	6.551500	0.000000	1.800000	242.719040
156.175003	6.551500	0.000000	1.800000	242.719040
164.537506	6.551500	0.000000	1.800000	242.719040
172.900009	6.551500	0.000000	1.800000	242.719040
180.788895	6.470617	-0.020505	1.800000	236.763000
188.677780	6.227969	-0.041011	1.800000	219.338730
196.566681	5.823555	-0.061516	1.800000	191.777969
204.455566	5.257376	-0.082022	1.800000	156.300552
212.344452	4.529432	-0.102527	1.800000	116.013863
220.233337	3.639723	-0.123033	1.800000	74.913322
228.122238	2.588246	-0.143538	1.800000	37.882038
236.011124	1.375006	-0.164044	1.800000	10.691321
243.900009	0.000000	-0.184549	1.800000	0.000000

HYDROSTATIC QUANTITIES (ALL QUANTITIES FOR SINGLE HULL)

TOTAL DISPLACED VOLUME = 0.527068E+05
LOWER HULL DISPLACED VOLUME = 0.425810E+05

```
LOWER HULL DESCRIPTION
----------------------
    CENTERLINE LENGTH                                              =     243.900009
    TOE-OUT ANGLE                                                  =   0.0000 (DEG)
    NOSE-UP ANGLE                                                  =   0.0000 (DEG)

    NOSE AT:                                                  X    =     -16.470001
                                                              Y    =      38.500000
                                                              Z    =     -15.559999

    TAIL AT:                                                  X    =     227.430008
                                                              Y    =      38.500000
                                                              Z    =     -15.559999

    MIDSHIP POSITION:                   CENTERLINE DEPTH,  H    =      15.560000
                              CENTERLINE-STRUT  DISTANCE,  D    =       0.000000

    MAXIMUM DRAFT AT:                                         X    =     156.430038
                                                              Y    =      38.500000
                                                              Z    =     -22.111502

    MAXIMUM BEAM AT:                                          X    =     148.419312
                                                              Y    =      50.291672
                                                              Z    =     -15.551149

    ELLIPTIC CHORD RATIO                                    CEL    =       1.800000
    START OF BLENDING TO CIRCULAR SECTIONS                  XEF    =     250.000000
    START OF CIRCULAR SECTIONS                              XEA    =     260.000000
     NOTE: XEF,XEA ARE IN LOWER HULL COORDINATES

INITIAL LOWER HULL DESCRIPTION
------------------------------
    LOWER HULL IS DESCRIBED PARAMETRICALLY                 ICRV    = 4
    ELLIPTIC NOSE SECTION LENGTH                            HL1    =     106.000000
    PARALLEL MID-SECTION LENGTH                             HL2    =      66.900002
    PARABOLIC TAIL SECTION LENGTH                           HL3    =      71.000000
    MID-SECTION RADIUS                                     RMAX    =       6.551500
```

Pages D-6 to D-11 show the SWATHGEN Printout for T-AGOS.

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------------------------------------------------------------------------------

TAGOS - SHIP SCALE - MODEL 1
------------------------------------------------------------------------------

    NOTE: ALL POSITIONS ARE GIVEN IN THE GLOBAL COORDINATE SYSTEM EXCEPT
          THE LOWER HULL RADII GIVEN ALONG THE CENTERLINE.

BOX DESCRIPTION
---------------
    BOX LENGTH                                          =    199.499985
    BOX DEPTH                                    BDD    =      2.000000
    BOX CLEARANCE                                BDC    =     15.000000
    FORWARD OVERHANG                             BDF    =      0.000000
    AFT OVERHANG                                 BDA    =      0.000000
    BOX WIDTH                                    BDW    =     77.000000

STRUT DESCRIPTION
-----------------
    LENGTH BETWEEN PERPENDICULARS                       =    199.500000
    ELLIPTIC FOREBODY LENGTH                     SL1    =    154.500000
    PARALLEL MIDBODY LENGTH (WATERPLANE)         SL2    =      6.800000
    PARABOLIC TAIL LENGTH                        SL3    =     38.200001
    MIDBODY THICKNESS                            SLT    =      7.000000
    OVERHANG LENGTH FROM FAIRING TRAILING        SOV    =      0.000000
    PARABOLIC TAIL LENGTH FOR FAIRING            SF3    =     38.200001
    OVERHANG HEIGHT                                Z    =      0.000000

    TRANSVERSE TAPER HALF ANGLE                  SAT    =   0.0000 (DEG)
    LEADING EDGE INCLINATION ANGLE               SAF    =   0.0000 (DEG)
    TRAILING EDGE INCLINATION ANGLE              SAA    =   0.0000 (DEG)

    CANT ANGLE                                   SAC    =   0.0000 (DEG)
    TOE-OUT ANGLE                                STO    =   0.0000 (DEG)
    LEADING EDGE - WATERPLANE SEPERATION         SSS    =     77.000000
```

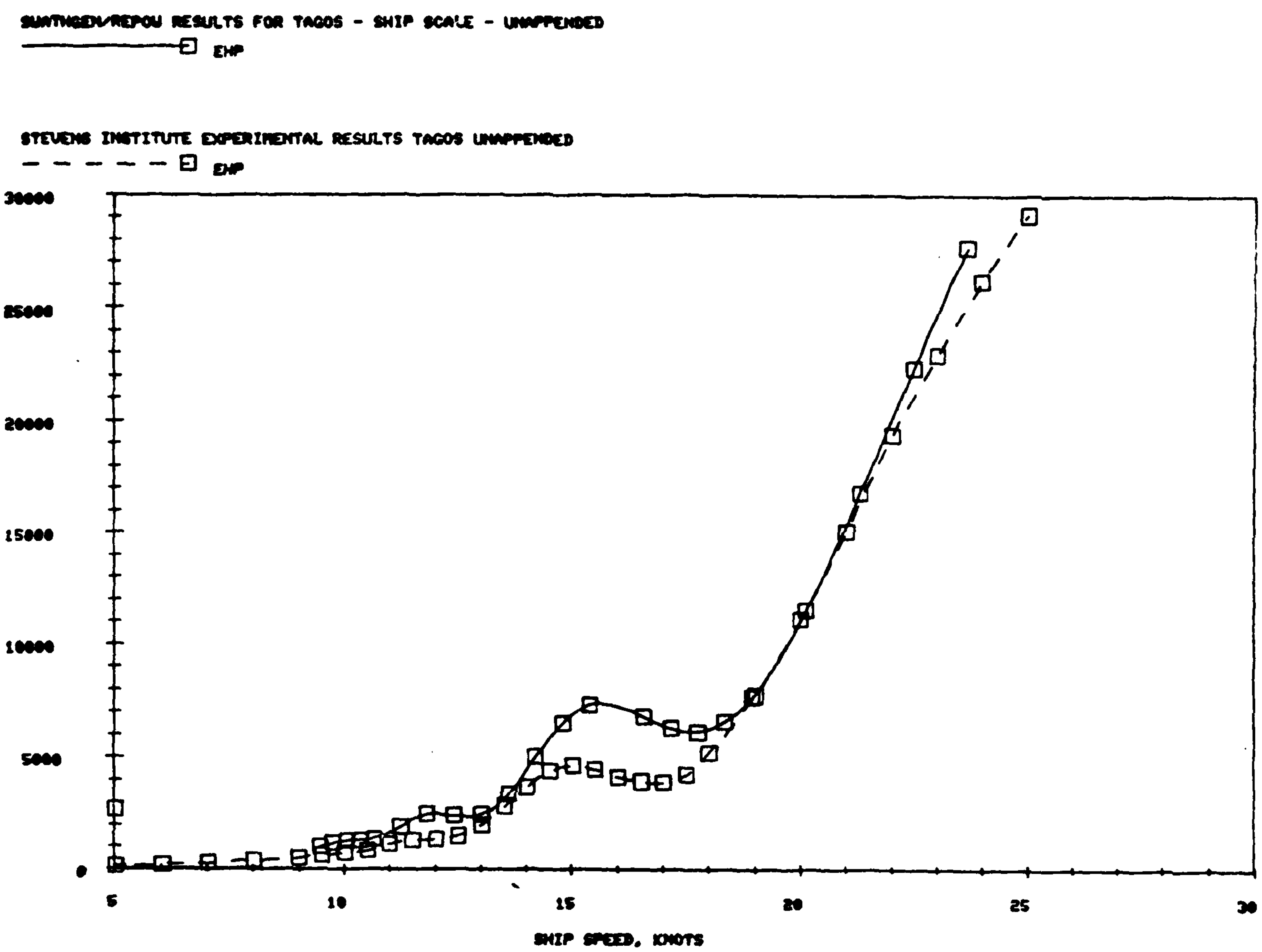

Figure D-4. T-AGOS EHP Comparison

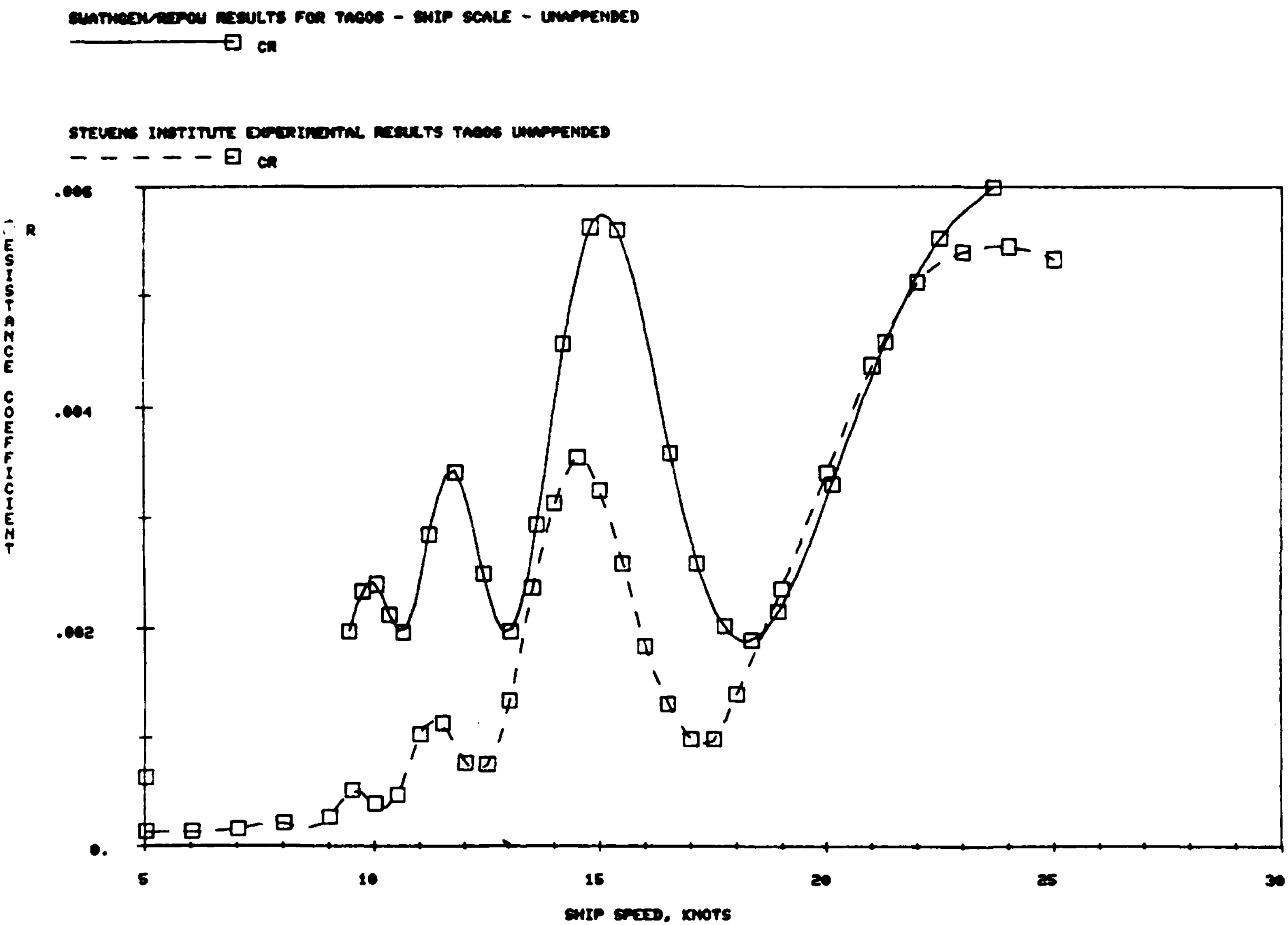

Figure D-3. T-AGOS Wave Resistance Coefficient

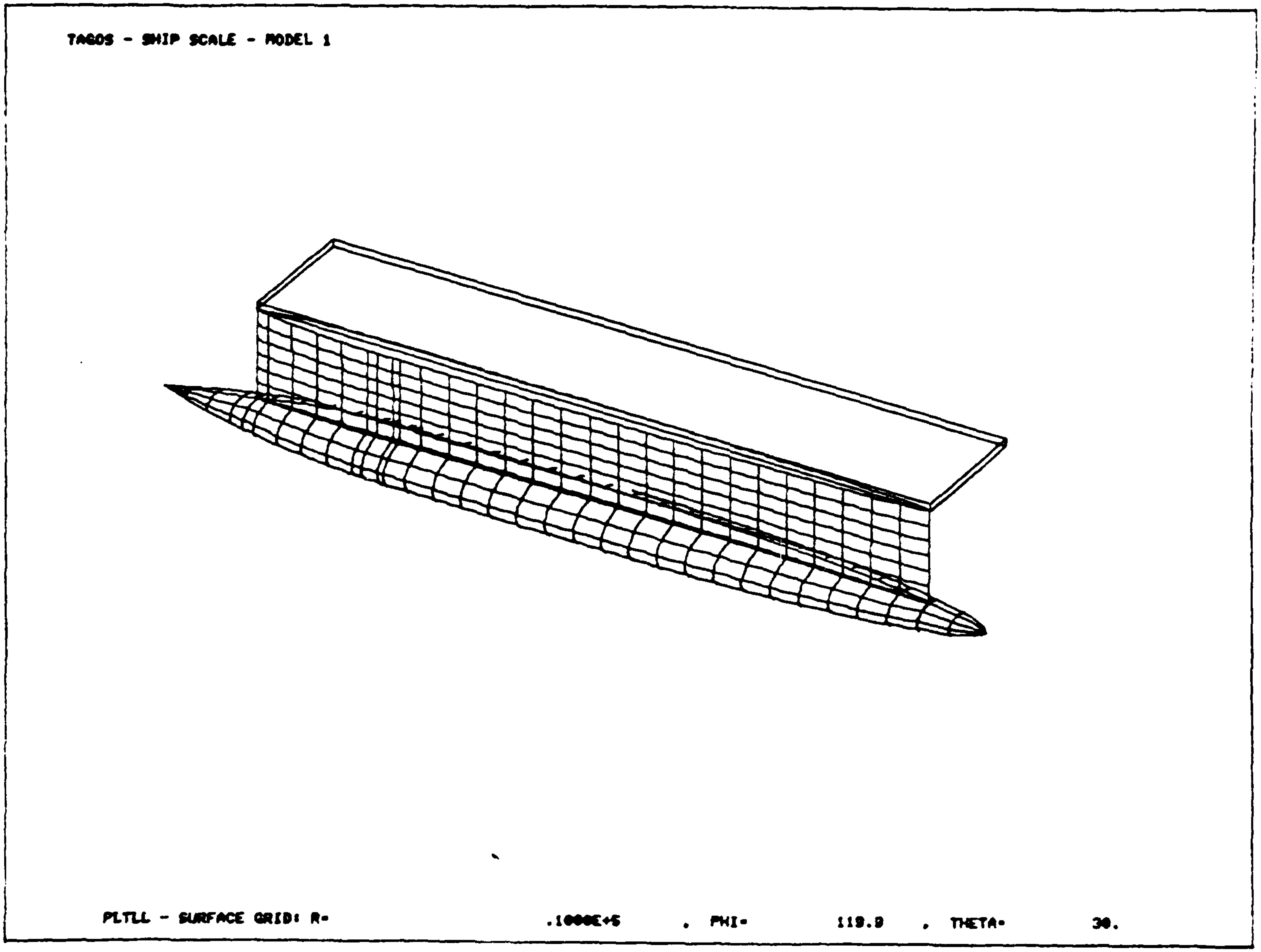

Figure D-2. SWATHGEN T-AGOS

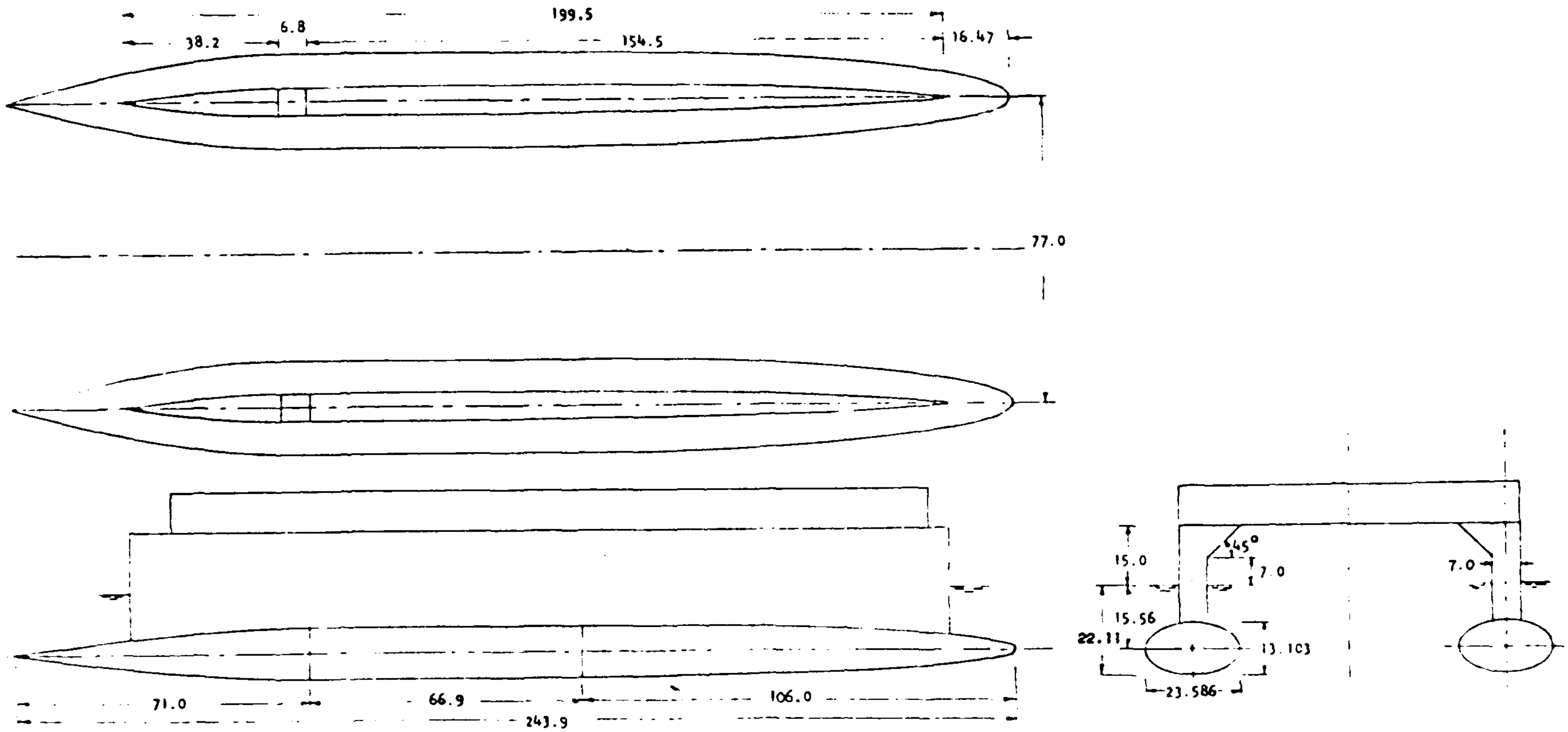

Figure D-1. SWATH T-AGOS Baseline Configuration (all dimensions in feet)
(from Davidson Laboratory Report SIT-DL-81-9-2216)

Appendix D REPOW VERIFICATION - T-AGOS

Geometry and resistance data were obtained for T-AGOS, tested by Davidson Laboratory. T-AGOS had a simple strut with an uncontoured, elliptical lower hull. The geometry from Davidson Laboratory Report SIT-DL-81-9-2216 is shown in Figure D-1. The SWATHGEN output data is in Appendix D and the SWATHGEN representation is shown in Figure D-2. The comparison of wave resistance coefficients is shown in Figure D-3 and EHP in Figure D-4.

The remainder of the appendix contains the SWCOMS data files and REPOW output for T-AGOS.

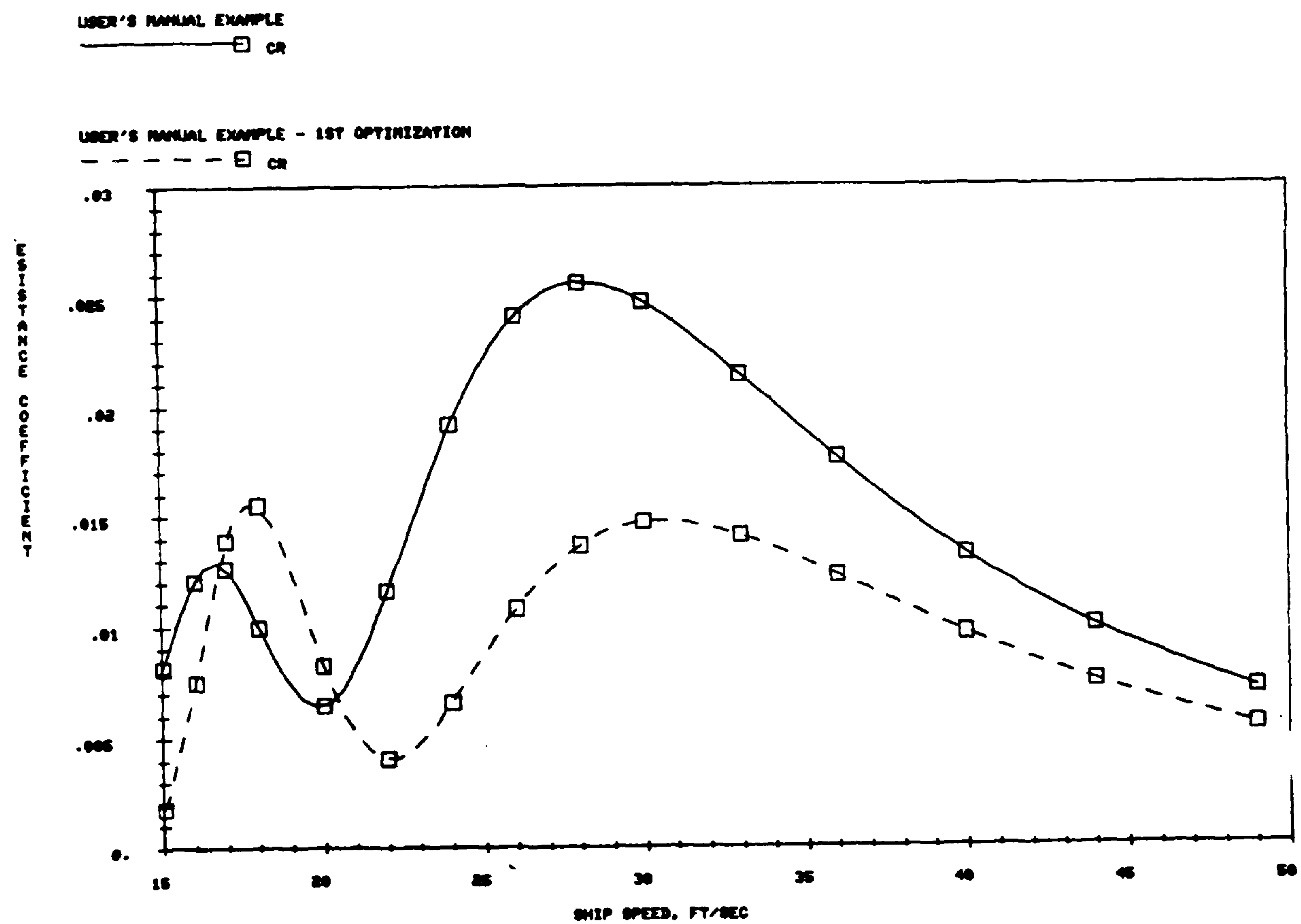

Figure C-14. Wave Resistance Coefficients, Original vs Optimized Forms.

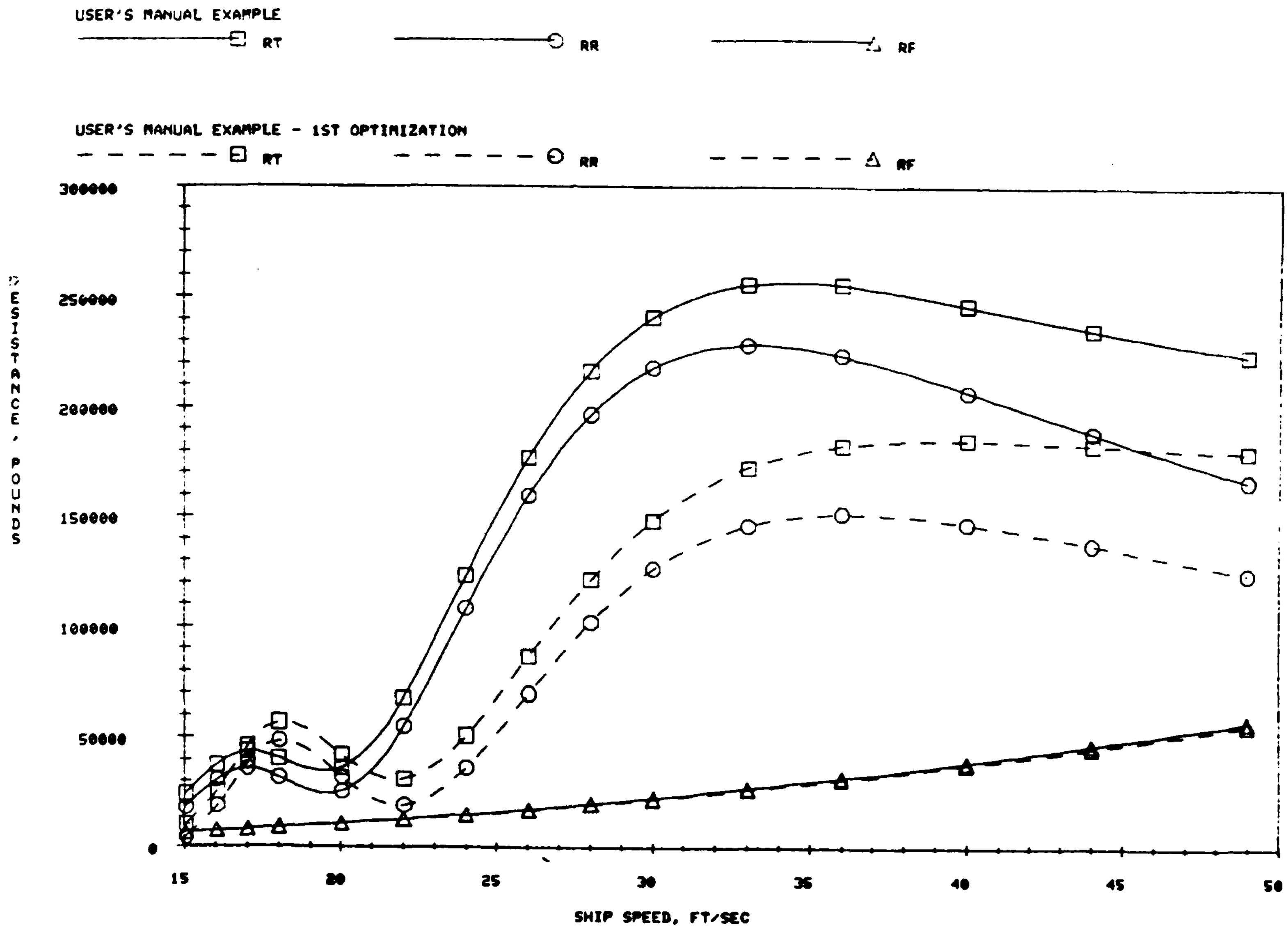

Figure C-13. Resistance Comparison, Original vs Optimized Forms.

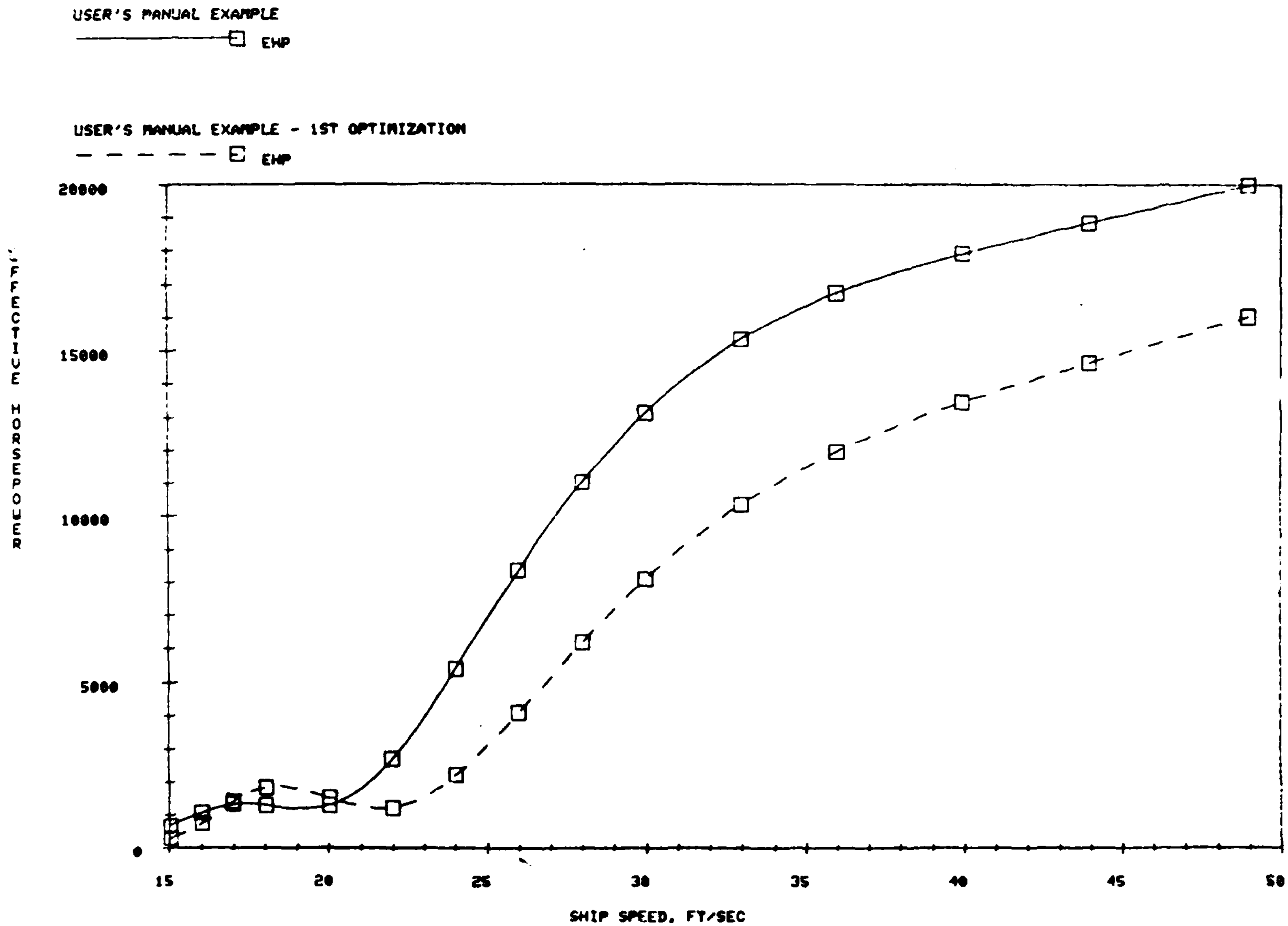

Figure C-12. EHP Comparison, Original vs Optimized Forms.

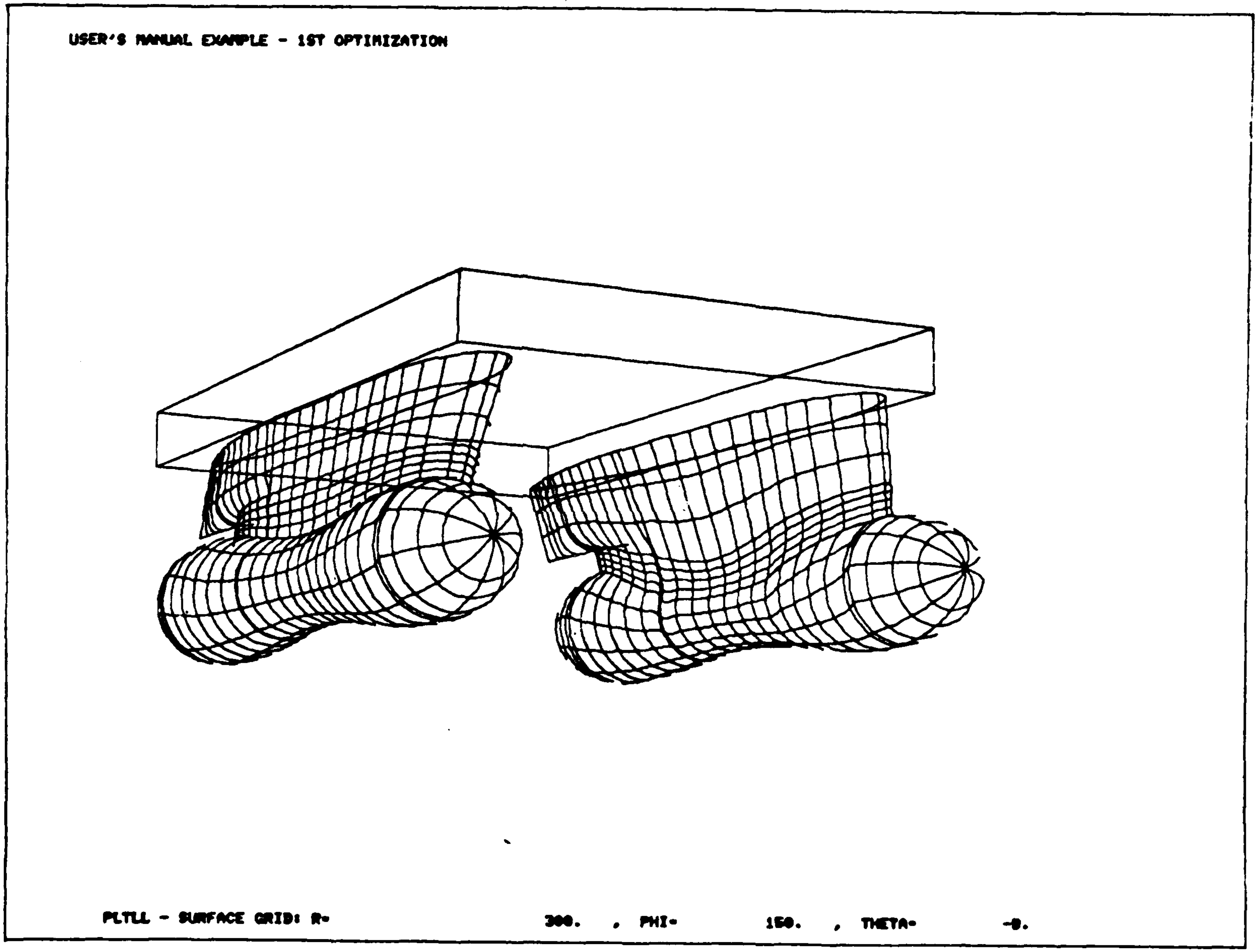

Figure C-11. Faired Hull (looking aft) Optimized Form.

TOTAL NUMBER OF HULL PANELS	=	880
NUMBER OF PANELS LENGTHWISE	=	34
NUMBER OF PANELS GIRTHWISE	=	30

I INDEXES THE ALPHA LENGTHWISE SURFACE PARAMETER
J INDEXES THE BETA GIRTHWISE SURFACE PARAMETER

THE I's CORRESPOND TO LONGITUDINAL DIVISIONS OF THE HULL SURFACE AS FOLLOWS:

NOSE	I = 1
STRUT LEADING EDGE	I = 4- 5
STRUT TRAILING EDGE	I = 32-33
TAIL	I = 37

THE J's CORRESPOND TO REGIONS OF THE HULL SURFACE AS FOLLOWS:

INBOARD STRUT SURFACE	$1 \leq J \leq 7$
INBOARD STRUT-HULL FAIRING	$8 \leq J \leq 12$
INBOARD HULL SURFACE	$13 \leq J \leq 18$
OUTBOARD HULL SURFACE	$19 \leq J \leq 24$
OUTBOARD HULL-STRUT FAIRING	$25 \leq J \leq 29$
OUTBOARD STRUT SURFACE	$30 \leq J \leq 36$

Pages D-12 to D-15 show the REPOW output for T-AGOS.

```
>>>>>>  REPOW RESISTANCE AND POWERING PROGRAM OUTPUT <<<<<<
TAGOS - SHIP SCALE - UNAPPENDED


>>> PANEL DATA INPUT VERIFICATION <<<

                               STRUT       LOWER HULL   APPENDAGES      TOTAL
        NUMBER OF PANELS        181            39          ---           220
        NUMBER OF POINTS        220            48          ---           268
             FORM FACTOR       1.170         1.100         ---           ---
    EFFECTIVE LENGTH, FT   0.2015E+03   0.2439E+03         ---           ---
SURFACE AREA, 2 HULLS, FT^2 0.7713E+04  0.2113E+05   0.0000E+00   0.2885E+05


 >>> SOURCE DISTRIBUTION PROPERTIES -- TWO HULLS
       DISPLACED VOLUME, FT^3...0.1046E+06
      DISPLACEMENT, LONG TONS...0.2991E+04
           LCB, FT AFT OF FP...0.1062E+03
NET NORMALIZED SOURCE STRENGTH...0.2033E+00


 KINEMATIC VISCOSITY, FT/SEC^2 = 0.1279E-04
           DENSITY, SLUG/FT^3 = 0.1990E+01


*** NO APPENDAGES
```

SPEED, FT/S	SPEED, KT	SPEED/LENGTH RATIO	FROUDE #	EHP
16.00	9.47	0.607	0.181	0.9584E+03
16.50	9.77	0.626	0.186	0.1134E+04
17.00	10.07	0.644	0.192	0.1254E+04
17.50	10.36	0.663	0.198	0.1289E+04
18.00	10.66	0.682	0.203	0.1352E+04
19.00	11.25	0.720	0.214	0.1904E+04
20.00	11.84	0.758	0.226	0.2449E+04

21.00	12.43	0.796	0.237	0.2386E+04
22.00	13.03	0.834	0.248	0.2444E+04
23.00	13.62	0.872	0.260	0.3400E+04
24.00	14.21	0.910	0.271	0.5032E+04
25.00	14.80	0.948	0.282	0.6539E+04
26.00	15.39	0.986	0.294	0.7321E+04
28.00	16.58	1.062	0.316	0.6811E+04
29.00	17.17	1.099	0.327	0.6296E+04
30.00	17.76	1.137	0.339	0.6145E+04
31.00	18.35	1.175	0.350	0.6582E+04
32.00	18.95	1.213	0.361	0.7674E+04
34.00	20.13	1.289	0.384	0.1155E+05
36.00	21.31	1.365	0.406	0.1680E+05
38.00	22.50	1.441	0.429	0.2238E+05
40.00	23.68	1.516	0.452	0.2766E+05

SPEED, FT/S	RT, LB	CT	RR, LB	CR
16.00	0.3295E+05	0.4483E-02	0.1450E+05	0.1973E-02
16.50	0.3778E+05	0.4834E-02	0.1823E+05	0.2332E-02
17.00	0.4059E+05	0.4892E-02	0.1990E+05	0.2398E-02
17.50	0.4050E+05	0.4606E-02	0.1864E+05	0.2120E-02
18.00	0.4130E+05	0.4440E-02	0.1824E+05	0.1961E-02
19.00	0.5511E+05	0.5318E-02	0.2957E+05	0.2853E-02
20.00	0.6734E+05	0.5864E-02	0.3920E+05	0.3413E-02
21.00	0.6250E+05	0.4937E-02	0.3163E+05	0.2498E-02
22.00	0.6110E+05	0.4397E-02	0.2739E+05	0.1971E-02
23.00	0.8130E+05	0.5353E-02	0.4461E+05	0.2938E-02
24.00	0.1153E+06	0.6973E-02	0.7554E+05	0.4568E-02
25.00	0.1438E+06	0.8017E-02	0.1009E+06	0.5622E-02
26.00	0.1549E+06	0.7980E-02	0.1086E+06	0.5595E-02
28.00	0.1338E+06	0.5944E-02	0.8052E+05	0.3577E-02
29.00	0.1194E+06	0.4946E-02	0.6247E+05	0.2587E-02
30.00	0.1127E+06	0.4360E-02	0.5192E+05	0.2010E-02
31.00	0.1168E+06	0.4232E-02	0.5214E+05	0.1890E-02
32.00	0.1319E+06	0.4487E-02	0.6325E+05	0.2152E-02
34.00	0.1869E+06	0.5631E-02	0.1098E+06	0.3310E-02
36.00	0.2566E+06	0.6897E-02	0.1708E+06	0.4590E-02
38.00	0.3240E+06	0.7815E-02	0.2288E+06	0.5520E-02
40.00	0.3803E+06	0.8280E-02	0.2754E+06	0.5997E-02

SPEED, FT/S	RF,LB	CF	RFS,LB	CFS
16.00	0.1845E+05	0.2510E-02	0.4208E+04	0.2141E-02
16.50	0.1955E+05	0.2502E-02	0.4457E+04	0.2132E-02
17.00	0.2069E+05	0.2494E-02	0.4712E+04	0.2124E-02
17.50	0.2186E+05	0.2486E-02	0.4973E+04	0.2116E-02
18.00	0.2305E+05	0.2479E-02	0.5242E+04	0.2108E-02
19.00	0.2554E+05	0.2464E-02	0.5798E+04	0.2092E-02
20.00	0.2815E+05	0.2451E-02	0.6380E+04	0.2078E-02
21.00	0.3087E+05	0.2438E-02	0.6989E+04	0.2064E-02
22.00	0.3372E+05	0.2427E-02	0.7623E+04	0.2052E-02
23.00	0.3668E+05	0.2415E-02	0.8283E+04	0.2040E-02
24.00	0.3977E+05	0.2405E-02	0.8968E+04	0.2028E-02
25.00	0.4297E+05	0.2395E-02	0.9679E+04	0.2017E-02
26.00	0.4629E+05	0.2385E-02	0.1041E+05	0.2007E-02
28.00	0.5327E+05	0.2367E-02	0.1196E+05	0.1988E-02
29.00	0.5694E+05	0.2358E-02	0.1277E+05	0.1978E-02
30.00	0.6073E+05	0.2350E-02	0.1361E+05	0.1970E-02
31.00	0.6463E+05	0.2343E-02	0.1447E+05	0.1961E-02
32.00	0.6864E+05	0.2335E-02	0.1535E+05	0.1953E-02
34.00	0.7702E+05	0.2321E-02	0.1720E+05	0.1938E-02
36.00	0.8586E+05	0.2308E-02	0.1914E+05	0.1924E-02
38.00	0.9515E+05	0.2295E-02	0.2118E+05	0.1911E-02
40.00	0.1049E+06	0.2284E-02	0.2331E+05	0.1898E-02

SPEED, FT/S	RFH,LB	CFH	RAPP, LB	RCORR, LB
16.00	0.1056E+05	0.1962E-02	0.0000E+00	0.3675E+04
16.50	0.1119E+05	0.1954E-02	0.0000E+00	0.3908E+04
17.00	0.1183E+05	0.1946E-02	0.0000E+00	0.4148E+04
17.50	0.1249E+05	0.1939E-02	0.0000E+00	0.4396E+04
18.00	0.1316E+05	0.1931E-02	0.0000E+00	0.4651E+04
19.00	0.1456E+05	0.1918E-02	0.0000E+00	0.5182E+04
20.00	0.1602E+05	0.1905E-02	0.0000E+00	0.5742E+04
21.00	0.1755E+05	0.1892E-02	0.0000E+00	0.6330E+04
22.00	0.1915E+05	0.1881E-02	0.0000E+00	0.6948E+04
23.00	0.2081E+05	0.1870E-02	0.0000E+00	0.7593E+04
24.00	0.2253E+05	0.1860E-02	0.0000E+00	0.8268E+04
25.00	0.2432E+05	0.1850E-02	0.0000E+00	0.8972E+04
26.00	0.2617E+05	0.1840E-02	0.0000E+00	0.9704E+04
28.00	0.3006E+05	0.1823E-02	0.0000E+00	0.1125E+05
29.00	0.3210E+05	0.1815E-02	0 [illegible]00E+00	0.1207E+05
30.00	0.3420E+05	0.1807E-02	0.0000E+00	0.1292E+05

31.00	0.3636E+05	0.1799E-02	0.0000E+00	0.1379E+05
32.00	0.3859E+05	0.1792E-02	0.0000E+00	0.1470E+05
34.00	0.4323E+05	0.1778E-02	0.0000E+00	0.1659E+05
36.00	0.4811E+05	0.1765E-02	0.0000E+00	0.1860E+05
38.00	0.5324E+05	0.1753E-02	0.0000E+00	0.2073E+05
40.00	0.5861E+05	0.1742E-02	0.0000E+00	0.2297E+05

*** SH = TOTAL UNAPPENDED LOWER HULL SURFACE AREA
*** SS = TOTAL UNAPPENDED STRUT SURFACE AREA
*** ST = SS+ST = TOTAL UNAPPENDED SURFACE AREA
*** ELH = LOWER HULL EFFECTIVE LENGTH = CENTERLINE LENGTH
*** ELS = STRUT EFFECTIVE LENGTH = MEAN BELOW WATERLINE LENGTH
*** FROUDE NUMBER BASED ON ELH
*** RCOR = CORRELATION ALLOWANCE
*** RAPP = APPENDAGE RESISTANCE

END

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